NOAA Technical Report NMFS 28

Review of Geographical Stocks of Tropical Dolphins (*Stenella* spp. and *Delphinus delphis*) in the Eastern Pacific

William F. Perrin, Michael D. Scott,
G. Jay Walker, and Virginia L. Cass

March 1985

LIBRARY

APR 19 1985

National Marine Fisheries Service
2570 Dole Street
Honolulu, Hawaii

NOAA
Tech.
Rept.
NMFS
28

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

NOAA TECHNICAL REPORTS NMFS

The major responsibilities of the National Marine Fisheries Service (NMFS) are to monitor and assess the abundance and geographic distribution of fishery resources, to understand and predict fluctuations in the quantity and distribution of these resources, and to establish levels for optimum use of the resources. NMFS is also charged with the development and implementation of policies for managing national fishing grounds, development and enforcement of domestic fisheries regulations, surveillance of foreign fishing off United States coastal waters, and the development and enforcement of international fishery agreements and policies. NMFS also assists the fishing industry through marketing service and economic analysis programs, and mortgage insurance and vessel construction subsidies. It collects, analyzes, and publishes statistics on various phases of the industry.

The NOAA Technical Report NMFS series was established in 1983 to replace two subcategories of the Technical Reports series: "Special Scientific Report—Fisheries" and "Circular." The series contains the following types of reports: Scientific investigations that document long-term continuing programs of NMFS, intensive scientific reports on studies of restricted scope, papers on applied fishery problems, technical reports of general interest intended to aid conservation and management, reports that review in considerable detail and at a high technical level certain broad areas of research, and technical papers originating in economics studies and from management investigations.

Copies of NOAA Technical Report NMFS are available free in limited numbers to governmental agencies, both Federal and State. They are also available in exchange for other scientific and technical publications in the marine sciences. Individual copies may be obtained from: U.S. Department of Commerce, National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

NMFS Honolulu Library
00000000004715

NOAA Technical Report NMFS 28

Review of Geographical Stocks of Tropical Dolphins (*Stenella* spp. and *Delphinus delphis*) in the Eastern Pacific

William F. Perrin, Michael D. Scott,
G. Jay Walker, and Virginia L. Cass

March 1985

U.S. DEPARTMENT OF COMMERCE
Malcolm Baldrige, Secretary
National Oceanic and Atmospheric Administration
John V. Byrne, Administrator
National Marine Fisheries Service
William G. Gordon, Assistant Administrator for Fisheries

Library
NOAA, National Marine Fisheries Service
SWFC Honolulu Laboratory F/SWC2
2570 Dole Street
Honolulu, HI 96822-2396

The National Marine Fisheries Service (NMFS) does not approve, recommend or endorse any propriety product or proprietary material mentioned in this publication. No reference shall be made to NMFS, or to this publication furnished by NMFS, in any advertising or sales promotion which would indicate or imply that NMFS approves, recommends or endorses any proprietary product or proprietary material mentioned herein, or which has as its purpose an intent to cause directly or indirectly the advertised product to be used or purchased because of this NMFS publication.

CONTENTS

Introduction ... 1
Materials and methods ... 2
  Morphological analyses ... 2
  Distribution data ... 4
    Stenella attenuata ... 4
    Stenella longirostris ... 5
    Tagging ... 6
Species accounts ... 8
  Stenella attenuata ... 8
  Stenella longirostris ... 14
  Stenella coeruleoalba ... 16
  Delphinus delphis ... 17
Origins of the geographical forms ... 21
Recommendations ... 23
  Stenella attenuata ... 23
  Stenella longirostris ... 23
  Stenella coeruleoalba ... 23
  Delphinus delphis ... 23
Acknowledgments ... 23
Literature cited ... 23
Appendix 1. Statistical reporting blocks for eastern tropical Pacific ... 26
Appendix 2. Stock composition of records of *Stenella longirostris* by 5° block ... 27-28

Figures

1. Known distribution of *Stenella attenuata* in the eastern Pacific, showing SOPS '79 species range and stock boundaries, and new species range ... 2
2. Known distribution of *Stenella longirostris* in the eastern Pacific, showing SOPS '79 species range and stock boundaries, and new species range ... 3
3. Known distribution of *Stenella coeruleoalba* in the eastern Pacific, showing SOPS '79 boundaries and new species range ... 3
4. Known distribution of *Delphinus delphis* in the eastern tropical Pacific, showing SOPS '79 species range and stock boundaries, and new species range ... 4
5. Collection localities for adult specimens of *Stenella attenuata* included in body-length analyses ... 5
6. Collection localities for adult specimens of *Stenella longirostris* included in body-length analyses ... 6
7. Collection localities for adult specimens of *Stenella coeruleoalba* included in body-length analyses ... 7
8. Collection localities for adult specimens of *Delphinus delphis* included in body-length analyses ... 8
9. Records of offshore and coastal spotted dolphins in the far-eastern Pacific ... 9
10. Records of offshore and coastal spotted dolphins off A) North America, B) Central America, and C) South America ... 10-11
11. Relative abundance of records of offshore and coastal spotted dolphins by distance from coast ... 11
12. Frequency distributions, ranges, means, and standard deviations of body length for male and female spotted dolphins, *Stenella attenuata*, from four geographical areas ... 12
13. Frequency distributions of ovarian-corpus count for northern and southern offshore samples of adult female spotted dolphins ... 13
14. Distribution of eastern and Costa Rican spinner dolphins in the eastern tropical Pacific ... 14
15. Distribution of eastern and Costa Rican spinner dolphins off Central America ... 15
16. Frequency distributions, ranges, means, and standard deviations of body length in samples of adult specimens of *Stenella longirostris* of four stocks ... 16
17. Distribution of whitebelly spinner dolphins in the eastern Pacific ... 17
18. Racial composition by 5° square of sightings of *Stenella longirostris* identified to geographical race ... 18
19. Frequency distributions of ovarian-corpus counts in northern and southern samples of adult female spotted dolphins ... 18
20. Records of *Stenella coeruleoalba* in the eastern Pacific ... 19
21. Length-frequency distribution and means of body length for northern tropical and southern tropical adult males and females of *Stenella coeruleoalba* ... 19
22. Frequency distributions, ranges, means, and standard deviations of length in two stocks of *Delphinus delphis* ... 20
23. Records of *Delphinus delphis* in the eastern tropical Pacific ... 20
24. Conceptual model of radial pattern of geographical variation in pelagic populations of *Stenella* in the eastern tropical Pacific ... 22
25. Recommended management units for *Stenella coeruleoalba* ... 24
26. Recommended management units for *Delphinus delphis* in the eastern tropical Pacific ... 24

Tables

1. Releases of spaghetti tags by Martini and Nilson aboard the private vessel *Serenity* in 1975 and 1976 7
2. Estimated school sizes for sightings of coastal and offshore spotted dolphins within 100 nmi of the coast 13
3. Records of Costa Rican and eastern forms of *Stenella longirostris* within 50 nmi of the coast, north and south of Gulf of Tehuantepec 15
4. Distances from coast of specimen records of *Delphinus delphis* in Square 189 and Squares 168-169 21

Review of Geographical Stocks of Tropical Dolphins (*Stenella* spp. and *Delphinus delphis*) in the Eastern Pacific

WILLIAM F. PERRIN,[1] MICHAEL D. SCOTT,[2] G. JAY WALKER,[1]
and VIRGINIA L. CASS[1]

ABSTRACT

Information on geographical variation is reviewed for *Stenella attenuata*, *S. longirostris*, *S. coeruleoalba*, and *Delphinus delphis* in the eastern tropical Pacific, and boundaries for potential management units are proposed. National Marine Fisheries Service and Inter-American Tropical Tuna Commission sighting records made from 1979 to 1983 which were outside boundaries used in a 1979 assessment were examined for validity. Tagging returns and morphological data were also analyzed. Several stock ranges are expanded or combined. Three management units are proposed for *S. attenuata*: the coastal, northern offshore, and southern offshore spotted dolphins. Four management units are proposed for *S. longirostris*: the Costa Rican, eastern, northern whitebelly, and southern whitebelly spinner dolphins. Two provisional management units are proposed for *S. coeruleoalba*: the northern and southern striped dolphins. Five management units (two of which are provisional) are proposed for *D. delphis*: the Baja neritic, northern, central, southern, and Guerrero common dolphins. Division into management units was based on morphological stock differences and distributional breaks.

INTRODUCTION

Tuna fishermen make use of four species of dolphins in the international purse-seine fishery for yellowfin tuna in the eastern tropical Pacific in finding and capturing the tuna (Smith 1983). These are (in order of importance to the fishery): the spotted dolphin, *Stenella attenuata*; the spinner dolphin, *S. longirostris*; the common dolphin, *Delphinus delphis*, and the striped dolphin, *S. coeruleoalba*. Perrin et al. (1983) delineated the known ranges of the species in the eastern Pacific in a recent review. The purpose of this paper is to review available information on geographical variation of the four species in the eastern Pacific and to propose boundaries for potential management units.

Geographical variation in *S. attenuata* and *S. longirostris* was first described by Perrin (1972a, b, 1975a). He placed the nominal endemic *S. graffmani* (Lönnberg 1934) (described from Acapulco, Mexico) in the synonymy of *S. attenuata* (Gray 1846) and described three subspecies from the eastern and Central Pacific: 1) the coastal spotted dolphin, *S. a. graffmani* (formerly *S. graffmani*), a relatively large and heavily spotted form thought to occur within about 20-25 km of the shore and in gulfs and embayments from southern Mexico to Colombia; 2) the offshore spotted dolphin, *S. a.* subsp. "A" (unnamed), a smaller and more lightly spotted pelagic form thought to occur from about 25 km offshore from Cabo San Lucas, Mexico, to Colombia and west to at least long. 145°W in tropical water; and 3) the Hawaiian spotted dolphin *S. a.* subsp. "B" (unnamed) from Hawaiian waters, similar to the offshore form but less spotted and with a larger skull. In the case of the spinner dolphins, specimens from the eastern tropical Pacific had been referred (by Hester et al. 1963) to *S. microps* (Gray 1846; described from an unknown locality) and animals from Hawaii referred (by Morris and Mowbray 1966) to *S. roseiventris* (Wagner 1846; described from the western Pacific). Perrin (1975a) considered the spinner dolphins to belong to a single species, *S. longirostris* (Gray 1848) (described from an unknown locality) and described four subspecies. The Costa Rican spinner dolphin, *S. l.* subsp. "A" (unnamed), is a relatively long and slender form of overall gray color and with a very long rostrum, from nearshore waters of Costa Rica and El Salvador. The eastern spinner dolphin, *S. l.* subsp. "B" (unnamed; formerly identified as *S. microps*), is a smaller but similarly colored form with a small skull and (in many adult males) with the dorsal fin canted forward almost so as to appear reversed and occurs westward from the coast of Mexico out to about 800 km. The whitebelly spinner dolphin (so called by tuna fishermen), *S. l.* subsp. "C" (unnamed), is similar to the eastern spinner dolphin in size and skull but has a ventrolateral white area extending from the flipper to the genital region and a less triangular dorsal fin; it ranges from about 800 km offshore to long. 140°W. The Hawaiian spinner dolphin, *S. l.* subsp. "D" (unnamed; formerly identified as *S. roseiventris*), is a relatively large form with large skull, sharply defined three-part color pattern and slightly falcate dorsal fin and occurs in Hawaiian waters. The first and last of these forms ("A" and "D") were at that time each known from only a few specimens, as were the coastal and Hawaiian forms of the spotted dolphin.

Perrin (1972a) described geographical variation in the color pattern of *S. longirostris* in detail and proposed a generalized model for variation in this and other delphinids. Under this scheme, the variation in the spinner dolphin is seen as variation in extent and density of a color-pattern component called the "dorsal overlay," with the overlay being modally darkest and most extensive in the Costa Rican and eastern forms and lightest and least extensive in the Hawaiian form. The color patterns of the various forms are thus perceived as variations on a theme rather than as discretely different patterns.

As more distributional data have accumulated, the known ranges of the several forms of *S. attenuata* and *S. longirostris* have

[1]Southwest Fisheries Center La Jolla Laboratory, National Marine Fisheries Service, NOAA, P.O. Box 271, La Jolla, CA 92038.
[2]Inter-American Tropical Tuna Commission, La Jolla, CA 92038.

expanded (Perrin 1975b; Perrin et al. 1982). Studies of material from below the Equator led to division of the offshore spotted dolphin and the whitebelly spinner dolphin each into northern and southern stocks by Perrin, Sloan, and Henderson (1979). They found the southern offshore spotted dolphin to be slightly smaller than the northern animal, with a larger skull and more distinct color pattern. The southern whitebelly spinner dolphin they found to be larger than the northern form, with coloration more resembling that of the Hawaiian form. These findings and additional distribution records were taken into account in the most recent delineation of the ranges, which was used in an exercise referred to below as "SOPS 1979" (for Status of Porpoise Stocks [Workshop], 1979) in 1979 (Smith 1983) (Figs. 1, 2). Scott (1981) and Alverson (1981) reviewed the ranges, the former incorporating data through 1980.

The range of *S. coeruleoalba* in the eastern Pacific has been divided into management units based solely on apparent latitudinal gaps in distribution (Smith 1983), yielding five units: "northern temperate," "northern tropical," "central tropical," "southern tropical" and "southern temperate" (Fig. 3). To date, geographical variation in this species in the eastern Pacific has not been studied.

Delphinus delphis varies morphologically a great deal in the eastern Pacific. Banks and Brownell (1969) referred a short-beaked offshore form and a long-beaked neritic form occurring off southern California and Baja California to *D. delphis* L. and *D. bairdii* Dall 1873, respectively. Van Bree and Purves (1972) reported material that showed intergradation in skull morphology between the two forms and concluded that they belong to the single species *D. delphis*. Evans (1975, 1982) described five forms in the eastern Pacific: 1) a relatively large form inhabiting waters inside the 100-fathom curve off southern California and Baja California, with a very long rostrum and a muted color pattern (later called the "Baja neritic" form); 2) and 3) small, short-beaked northern temperate and northern tropical forms; and 4) and 5) large short-beaked central and southern tropical forms delineated by apparent latitudinal gaps in distribution. He also suggested the possible existence of an "equatorial-oceanic" population inhabiting waters west of long. 95°W. On the basis of additional distribution data, Au et al.[3] modified the boundaries of the stocks and added a "southern temperate" stock (Fig. 4). They included all animals between lat. 3° and 15°N in the "central tropical" stock, not recognizing Evans' tentative "equatorial-oceanic" stock. In the 1979 stock assessment (Smith 1983), the Baja neritic and northern temperate stocks were combined into a single management unit. The stock structure of *D. delphis* was most recently reviewed by Scott (1981).

In this paper we review developments and data collected for the four species since the 1979 stock assessment.

MATERIALS AND METHODS

Morphological Analyses

The samples and methods used in analyses of variation in skull and body length in *S. attenuata* and *S. longirostris* are described in Schnell et al.[4] and Douglas et al. (1984). In addition to considera-

[3]Au, D. K. W., W. L. Perryman, and W. F. Perrin. 1979. Dolphin distribution and the relationship to environmental features in the eastern tropical Pacific. Southwest Fisheries Center Admin. Rep. LJ-79-43, 59 p.

[4]Schnell, G. D., M. E. Douglas, and J. D. Hough. 1982. Geographic variation in morphology of spotted and spinner dolphins (*Stenella attenuata* and *S. longirostris*) from the eastern tropical Pacific. Southwest Fisheries Center Admin. Rep. LJ-82-15C, 213 p.

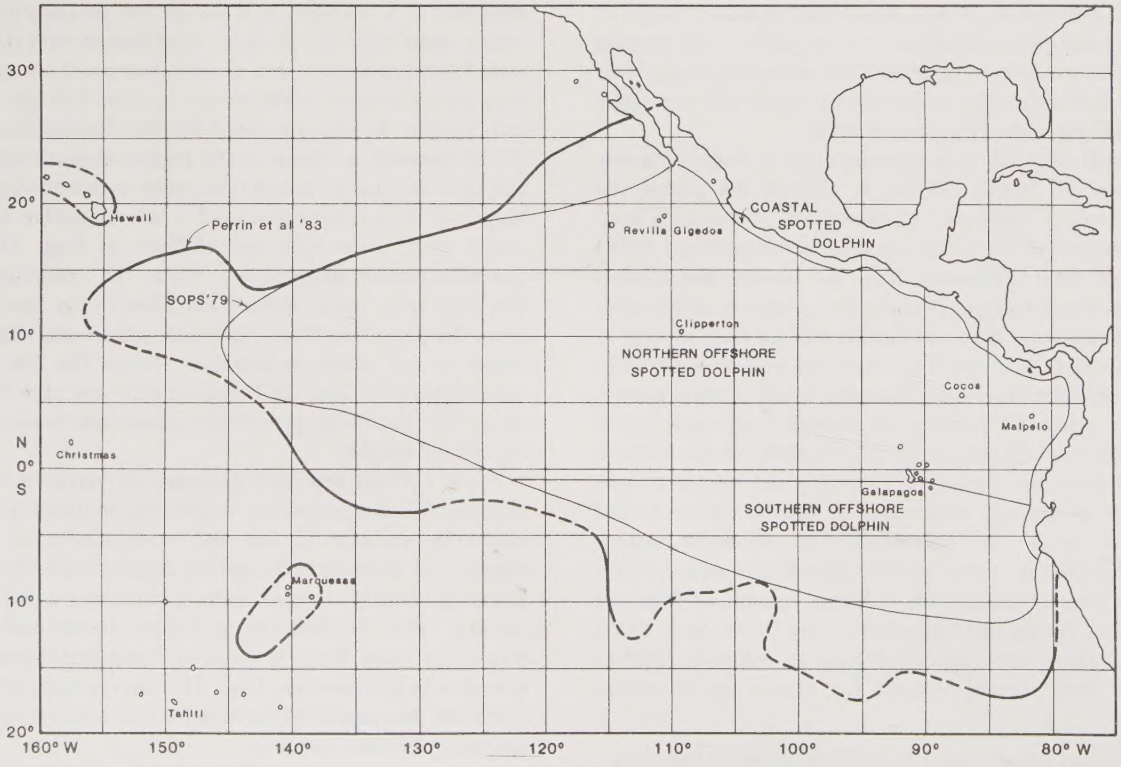


Figure 1.—Known distribution of *Stenella attenuata* in the eastern Pacific, showing SOPS '79 species range and stock boundaries, and new species range (from Perrin et al. 1983).

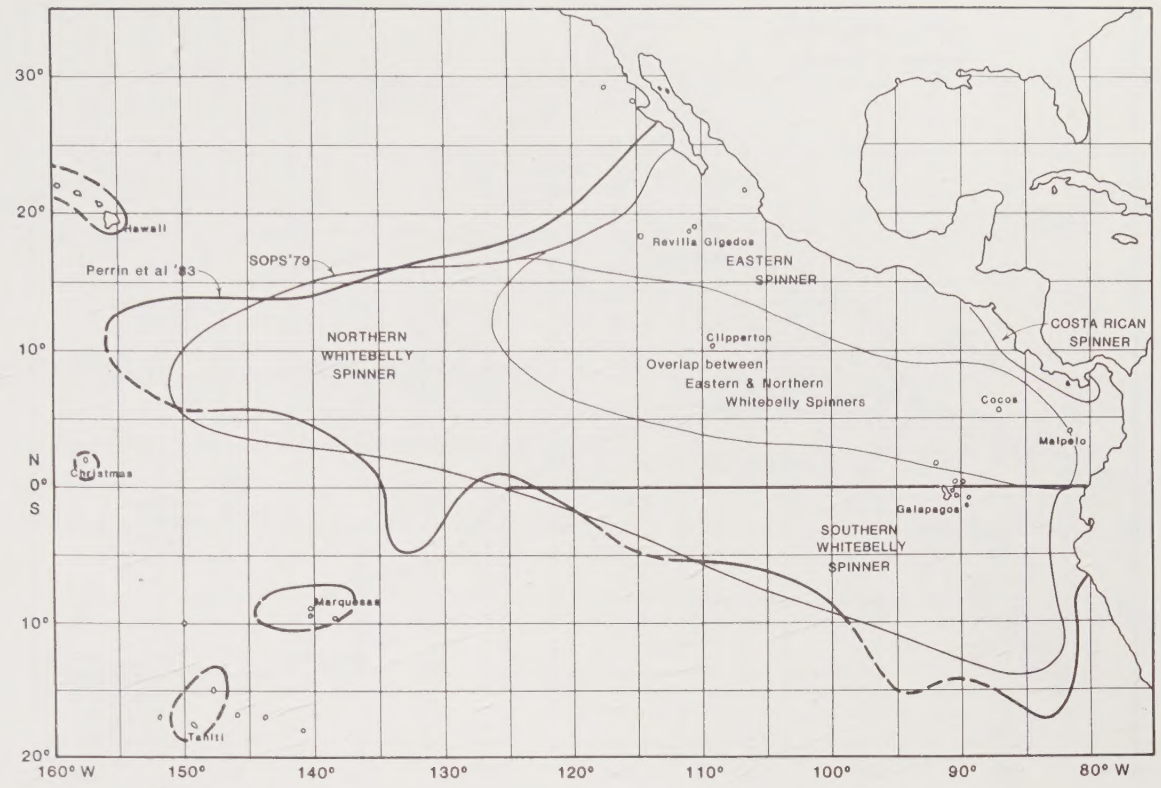


Figure 2.—Known distribution of *Stenella longirostris* in the eastern Pacific, showing SOPS '79 species range and stock boundaries, and new species range (from Perrin et al. 1983).

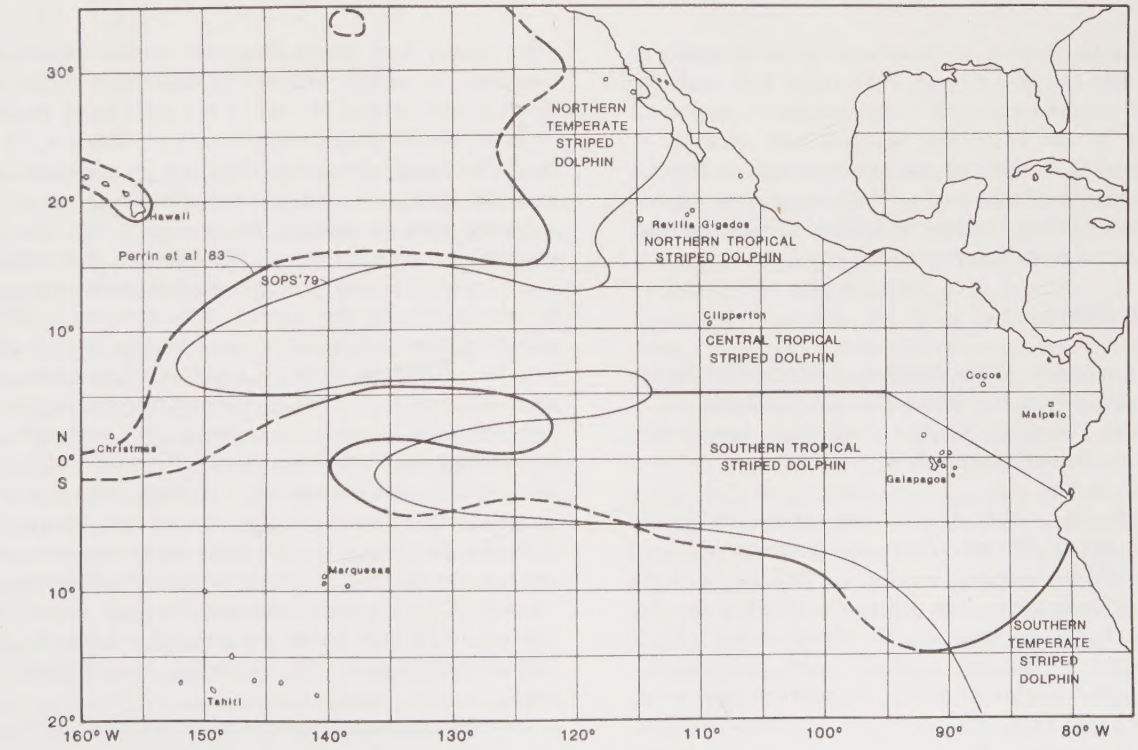


Figure 3.—Known distribution of *Stenella coeruleoalba* in the eastern Pacific, showing SOPS '79 boundaries and new species range (from Perrin et al. 1983).

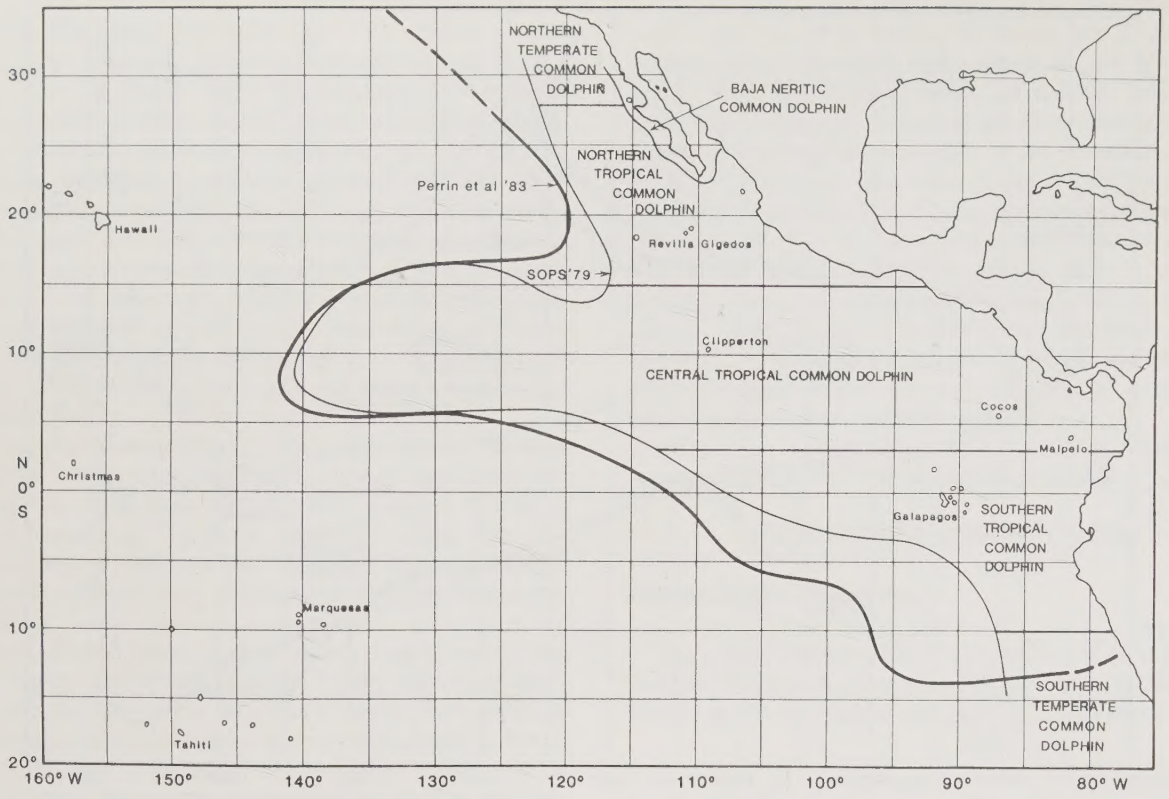


Figure 4.—Known distribution of *Delphinus delphis* in the eastern tropical Pacific, showing SOPS '79 species range and stock boundaries, and new species range (from Perrin et al. 1983).

tion of the results obtained by those authors, we reviewed all body-length data collected through 1981 (Figs. 5-8), including some data for the inshore forms of *S. attenuata* and *S. longirostris* not included in the contracted analyses, and data for *S. coeruleoalba* and *D. delphis*. We also examined data on frequencies of ovarian corpora for *S. attenuata* and *S. longirostris*. Sources of the data are described in Perrin and Oliver (1982); statistical reporting areas are defined in Appendix 1.

Distribution Data

The sources and nature of the distribution data are described in Perrin et al. (1983). Data were included for all NMFS and IATTC (Inter-American Tropical Tuna Commission) tuna/dolphin observer cruises from 1979 through most of 1983.

***Stenella attenuata*.**—We reviewed all records of spotted dolphins from within 100 nmi of the coast (or a coastal island) that were identified to stock ("coastal" or "offshore"). These comprised 1,650 sightings and collection records. Of 502 "coastal" records, we concurred with the identifications for 218; 67 were changed to "offshore," and 217 were downgraded to unidentified spotted dolphin. Of 1,147 "offshore" records, we accepted 456, changed 44 to "coastal," 640 to unidentified spotted dolphin, and 7 to unidentified dolphin. The large number of changes to unidentified spotted dolphin was occasioned by the fact that in recent years NMFS observers aboard commercial purse seiners have largely identified spotted dolphins to stock based only on locality without regard to morphological information, all those within 50 nmi of the coast being designated as "coastal" and all those outside 50 nmi as "offshore." In point of fact, the coastal form was described on the basis of skull characters, body size, and coloration (Perrin 1975a).

In reviewing a sighting, we considered the morphological observations recorded by the observer and any photographs, body-length data, life history data, and osteological specimens collected in association with the sighting. If the observer noted that the animals seemed larger and/or more heavily spotted than those seen far offshore, or, better, if the photos, length data, or specimens indicated this (based on the published information for the two forms), we considered the record to be a confirmed record of the coastal form. Because the question is one of modal differences between forms within a species, the identification was judgmental in many cases, especially if only a few animals were measured or if the observer's recorded comments were sketchy or ambiguous and voucher data and specimens were absent. We tried to err on the side of conservatism, relegating the more weakly supported sightings to the unidentified category, but undoubtedly we classified some sightings of the coastal form as "offshore" and vice versa.

In evaluating the observer's recorded information, we also considered such factors as sighting distance and conditions, experience of the observer, and quality of documentation and identifications for other sightings made by the same observer. In

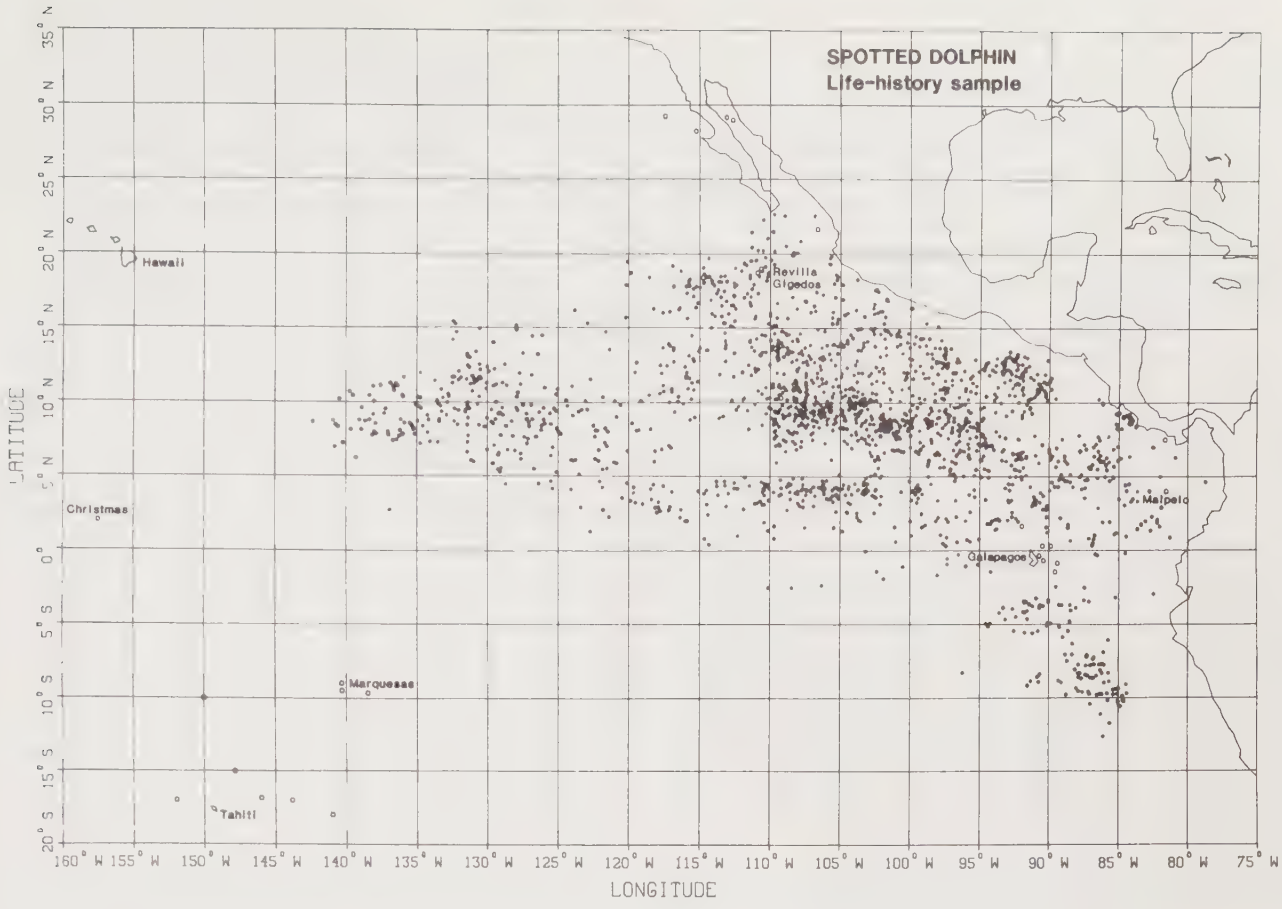


Figure 5.—Collection localities for adult specimens of *Stenella attenuata* included in body-length analyses. Adults defined as males with testis-epididymis weight of 100 g or more and females with at least one ovarian corpus. Open dots are small islands.

addition, we considered the context of the sighting record. If, for example, one net set (a sighting record) was made on the same school or near the same time and in the same area as a previous set assignable to stock based on recorded observations or specimens, we considered the second record to be of the same form.

***Stenella longirostris*.**—To examine the distribution of the Costa Rican spinner, we reviewed all records of *S. longirostris* within 50 nmi of the coast. The number of confirmable records was small, mainly because the Costa Rican form differs externally from the eastern form only in total body length and relative length of the rostrum and apparently not in coloration. Also, the Costa Rican spinner dolphin is only very rarely captured by tuna fishermen (Perrin 1975b). Of 42 "Costa Rican" records, we confirmed 33, assigning the rest to unidentified spinner. Of these confirmed records, 24 were based on aerial photographs taken during a photogrammetric experiment by the IATTC in 1980. One of 196 "eastern" records was judged to be "Costa Rican"; 28 were confirmed as "eastern," 157 changed to unidentified spinner, and 10 were accepted. One of 118 unidentified records was changed to "eastern."

We also reviewed all records of eastern spinner dolphins and whitebelly spinner dolphins outside the respective SOPS '79 boundaries (see Fig. 2). We again adopted a conservative stance because of the necessarily judgemental nature of the identifications in many cases. Of 198 "eastern" records, we confirmed 115 (8 supported by specimen data), assigned 40 to "whitebelly," 41 to unidentified spinner, and 2 to *S. attenuata*. Of 280 outlying "whitebelly" records, 184 were confirmed (1 with specimen data), 35 assigned to "eastern," 49 to unidentified spinner, 1 to *S. attenuata*, 1 to *Delphinus delphis*, and 10 to unidentified dolphin.

In addition to considering the sighting factors discussed above, we found it necessary to "second-guess" the observer's understanding of the modal nature of the differences between the two forms, as a large number of sightings of "mixed" schools of eastern and whitebelly spinner dolphins were reported. In some cases, this designation was likely valid, because the observer noted separate groups of the two forms in the net. In other cases we assigned the "mixed" sighting to one or the other of the two forms because only a very few individuals of the "other" type were seen, as would be expected in the case of subspecific-level modal difference. There were a large number of "mixed" sightings, however, where it was unclear from the information recorded if the record should be assigned to both forms. In some cases, color-pattern "intergrades" were reported, again something to be expected in the case of subspecific variation but difficult to evaluate when

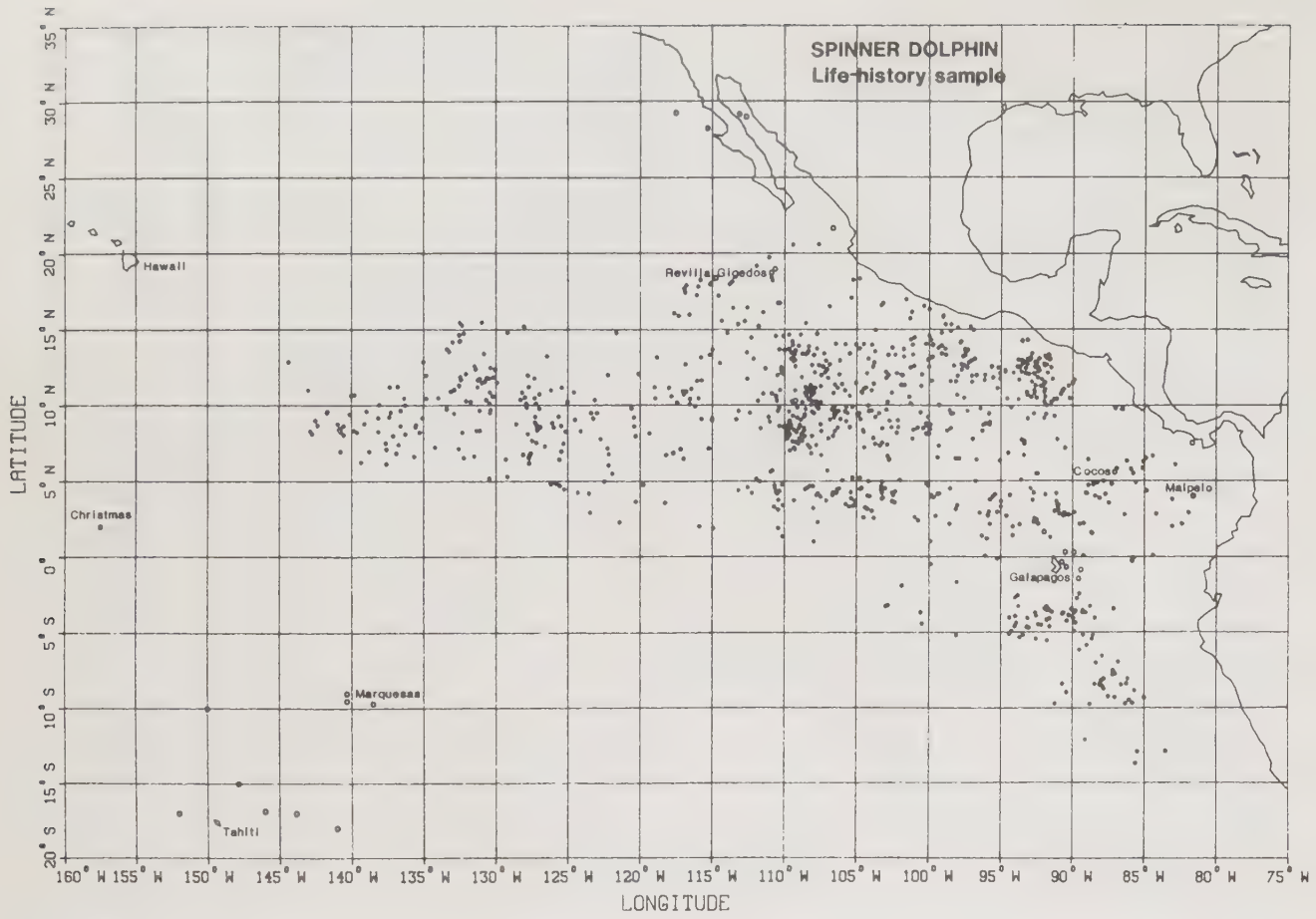


Figure 6.—Collection localities for adult specimens of *Stenella longirostris* included in body-length analyses. Adults defined as for *S. attenuata*. Specimens not identified to stock are not included.

assigning a school to one mode or the other or both. In these situations, we made judgmental decisions based on other aspects of the sightings, giving heavy weight to the experience and apparent knowledgability of the observer.

We noted three additional problems primarily encountered in sightings made by inexperienced observers, usually during the first few days of a first cruise:

1) Juvenile eastern spinner dolphins appear whitebelly-like in having a light ventrum (Perrin 1972a), and some were clearly misidentified in the sighting records. Where specimens were collected, we were able to detect the error; other instances probably remain in the whitebelly spinner dolphin records that we accepted.

2) Adult eastern spinner dolphins when seen at a distance, especially when spinning, appear slightly lighter ventrally then dorsally. In some cases it was clear that the observer had not yet seen whitebelly spinners and was mistaking this muted countershading for the sharply demarcated dark-gray and white pattern of the whitebelly form. Again, some instances of this have probably gone undetected in our review.

3) New observers in some cases clearly confused the similar fishermen's terms "whitebelly" (*Delphinus delphis*, *S. coeruleoalba* or *Lagenodelphis hosei*) and "whitebelly spinner" (*S. longirostris*). In an earlier review of species ranges (Perrin et al. 1983), we found that this had led to obviously spurious records of *S. longirostris* far north of the tropical habitat. Again, in the present review we found sightings (made at a distance) which members of the crew identified as "whitebellies" but the inexperienced observer identified as "whitebelly spinners," most likely misunderstanding the crewman's identification.

In view of these difficulties, and because of the rather unusual broad overlap of the ranges of geographical forms (which usually, by definition, are allopatric but may not be in these highly mobile and socially complex cetaceans), we consider the allocation of outlying sightings to whitebelly and eastern spinners on balance to be less reliable than the allocations for the other stocks and species reviewed in this study.

Tagging.—The tagging methods and operations (except for the tag releases listed in Table 1) have been described previously

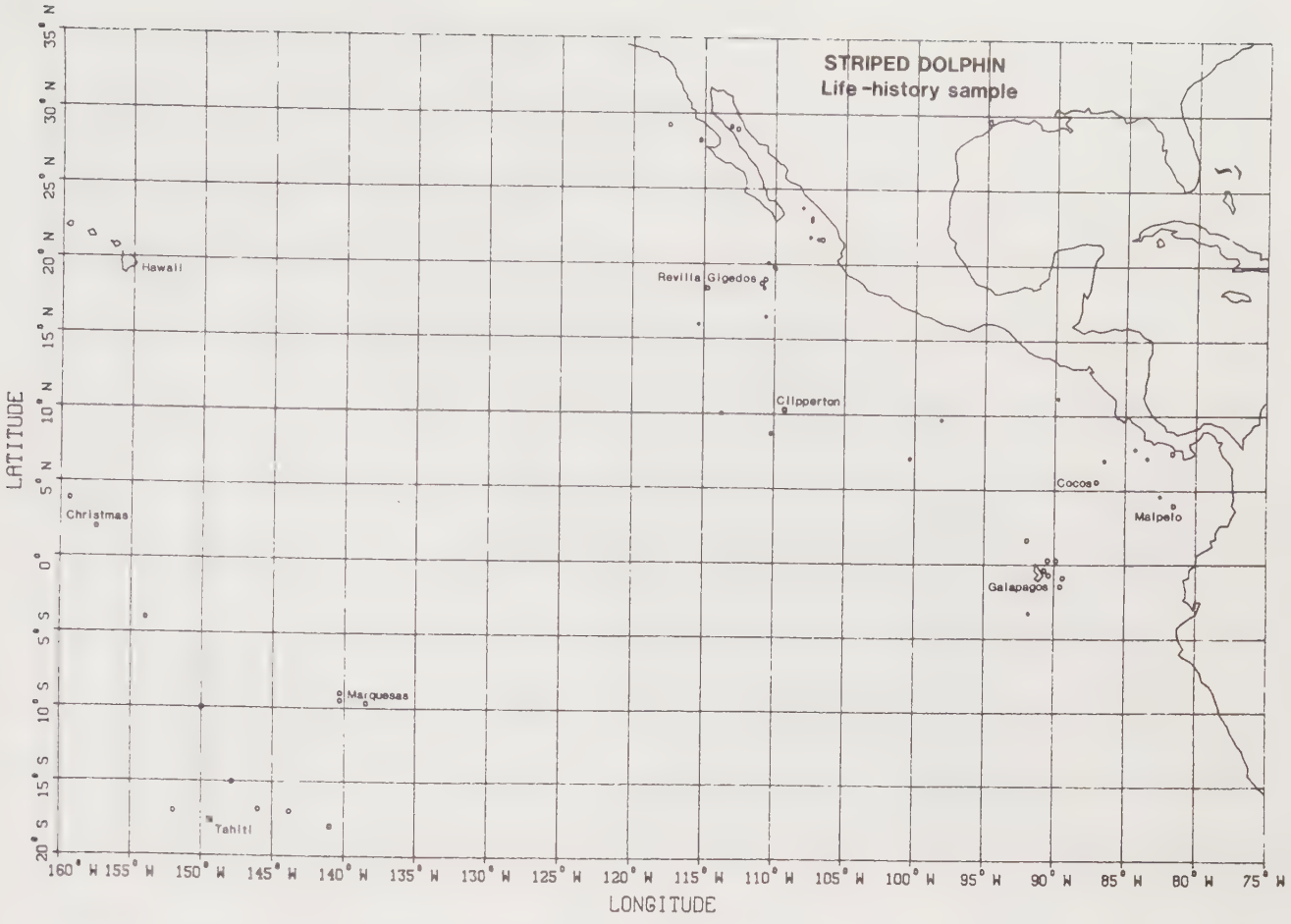


Figure 7.—Collection localities for adult specimens of *Stenella coeruleoalba* included in body-length analyses. Adults defined as for *S. attenuata*.

Table 1.—Releases of spaghetti tags (metal dart, type d—Perrin, Evans, and Holts 1979) by Martini and Nilson aboard the private vessel *Serenity* in 1975 and 1976. The species identifications are tentative.

Species	Tag no.	Date	Position (lat., long.)	Species	Tag no.	Date	Position (lat., long.)
S. attenuata	05002	27DEC75	8°20′N, 78°45′W	*Tursiops truncatus*[1]	05009	3JAN76	0°42′S, 89°30′W
	05004	27DEC75	8°13′N, 78°47′W		05010	3JAN76	0°42′S, 89°30′W
	05006	27DEC75	8°08′N, 78°50′W		05011	3JAN76	0°46′S, 89°30′W
	05007	27DEC75	8°07′N, 78°50′W		05012	3JAN76	0°46′S, 89°30′W
	05008	27DEC75	8°06′N, 78°50′W		05013	3JAN76	0°46′S, 89°30′W
	05017	27DEC75	8°07′N, 78°50′W		05015	3JAN76	0°46′S, 89°30′W
S. longirostris	05034	11MAR76	8°23′S, 137°36′W		05019	3JAN76	0°46′S, 89°30′W
	05036	12MAR76	8°42′S, 139°20′W		05021	3JAN76	0°46′S, 89°30′W
	05038	12MAR76	8°42′S, 139°40′W		05025	22JAN76	1°16′S, 90°22′W
	05040	20MAR76	8°58′S, 140°09′W		05028	24JAN76	0°50′S, 89°41′W
	05041	21MAR76	8°57′S, 140°03′W		05030	5FEB76	0°06′S, 90°52′W
	05043	21MAR76	8°56′S, 140°01′W		05033	16FEB76	0°38′S, 91°33′W
	05044	21MAR76	8°56′S, 140°01′W	Unidentified dolphin	05022	7JAN76	0°48′S, 90°11′W
	05046	22MAR76	8°55′S, 140°01′W	(*T. truncatus* or	05029	24JAN76	0°50′S, 89°41′W
	05047	23MAR76	8°57′S, 140°06′W	*Delphinus delphis*)	05031	16FEB76	0°38′S, 91°32′W

[1]Included here for completeness; these tagging data have not been published elsewhere.

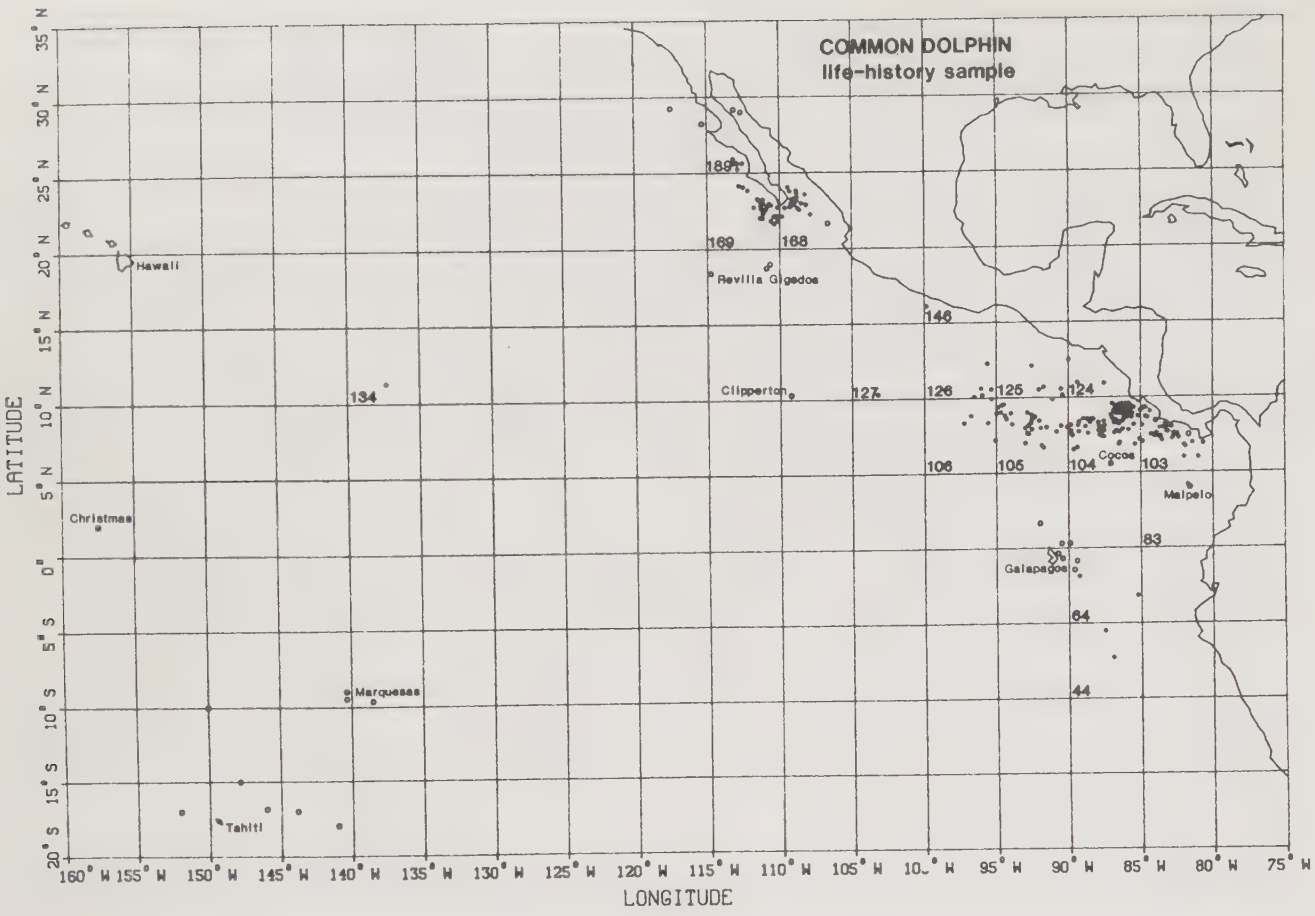


Figure 8.—Collection localities for adult specimens of *Delphinus delphis* included in body-length analyses. Adults defined as for *Stenella attenuata*. See Appendix 2 for square-numbering guide.

(Perrin, Evans, and Holts 1979; White et al. 1981; Jennings and Stives[5], Powers et al.[6]). Part of the results (tag recapture and resights) were presented and analyzed in Perrin, Evans, and Holts (1979) and Jennings and Stives (footnote 5).

SPECIES ACCOUNTS

Stenella attenuata

Our results for this species agree with those of similar earlier studies (Perrin 1975a, b; Perrin, Sloan, and Henderson 1979) and the results of the multivariate analyses by Schnell et al. (footnote 4). Our review of records within 100 nmi of the coast confirmed the existence of a relatively large-bodied, heavily spotted form living near the coast from northern Mexico to Ecuador (Fig. 9). The nearshore zone is not inhabited exclusively by the coastal form, however. There are well-supported records of the smaller, less-spotted offshore form within 20 nmi of the coast, in close proximity to well-supported records of the coastal form (Fig. 10A, B, C). Conversely, there are some well-supported records of the coastal form fairly well offshore, surrounded by records of the offshore form. The greatest distance from shore for a "coastal" record supported by body-length data was 70 nmi (off central Mexico), and the supported offshore record closest to the coast was at 16 nmi (also off central Mexico) (Figs. 10, 11). The transition from "coastal" to "offshore" is relatively regular out to about 60 nmi, with a continuing low frequency of sightings of the coastal form out to 90 nmi (Fig. 11). The distance at which the number of included records east of the line which are "offshore" is equal to the number of "coastal" records excluded (offshore of the line) is about 35 nmi. This, of course, is based on the distance-from-shore frequency distribution in the sample considered here. Within 50 nmi, the boundary used in the past in stock assessment and management, the composition (based on the stratification in Figure 11) was 52.7% "coastal" and 47.3% "offshore." A line drawn at 100 nmi from shore could safely be said to encompass all of the coastal range.

The coastal form may also occur around some of the oceanic islands in the eastern Pacific (Revilla Gigedos, Clipperton Island,

[5]Jennings, J. G., and R. K. Stives. 1979. Summary of preliminary results of a dolphin tagging feasibility study. Unpublished meeting document 79/32, Status of Porpoise Stocks Workshop, August 29-31, 1979, La Jolla, California, 22 p.

[6]Powers, J. E., R. W. Butler, J. G. Jennings, R. McLain, C. B. Peters, and J. DeBeer. 1979. Summary of research results from the fourth cruise of the Dedicated Vessel, September 12 to October 31st, 1978. Southwest Fisheries Center Admin. Rep. LJ-79-14, 46 p.

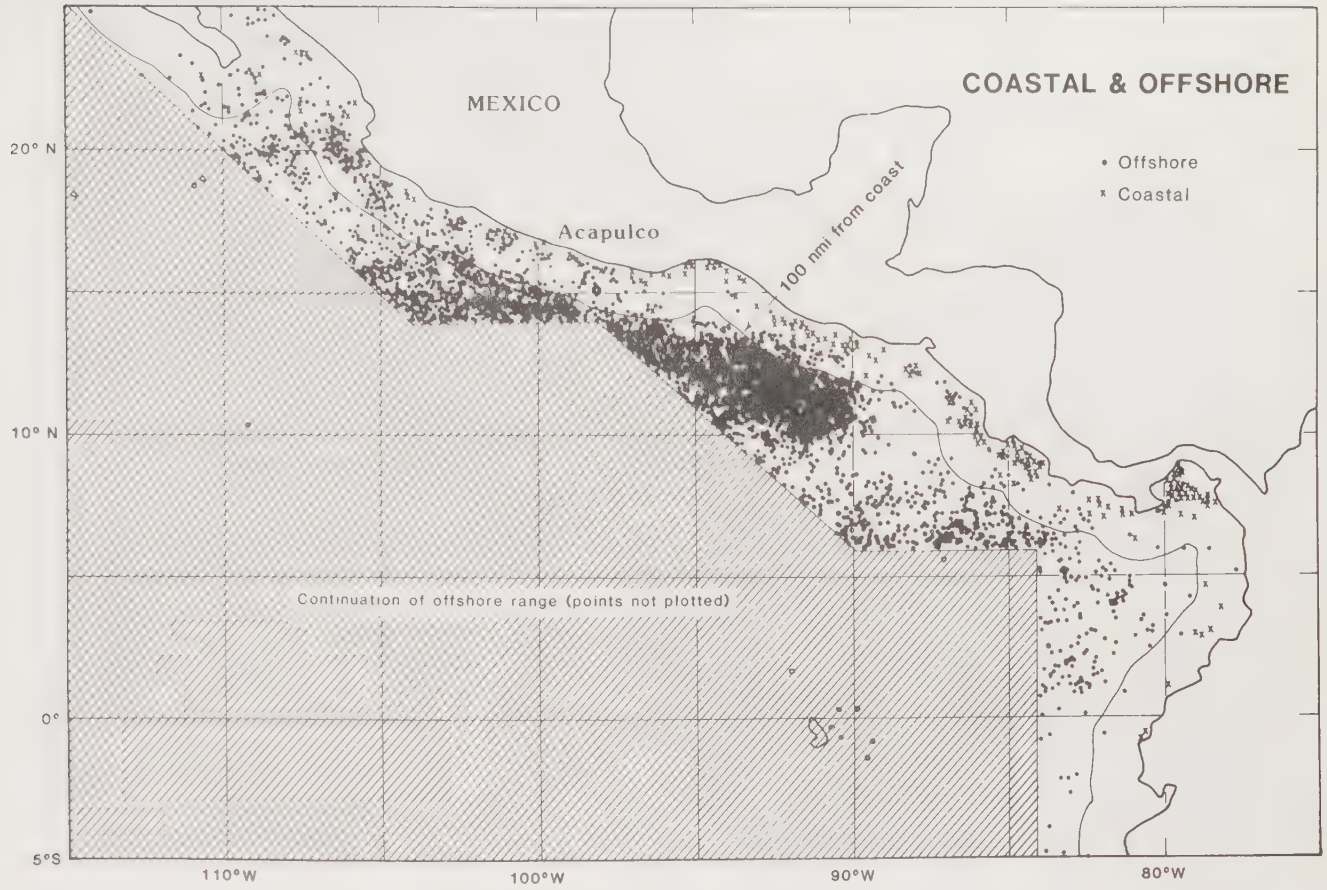


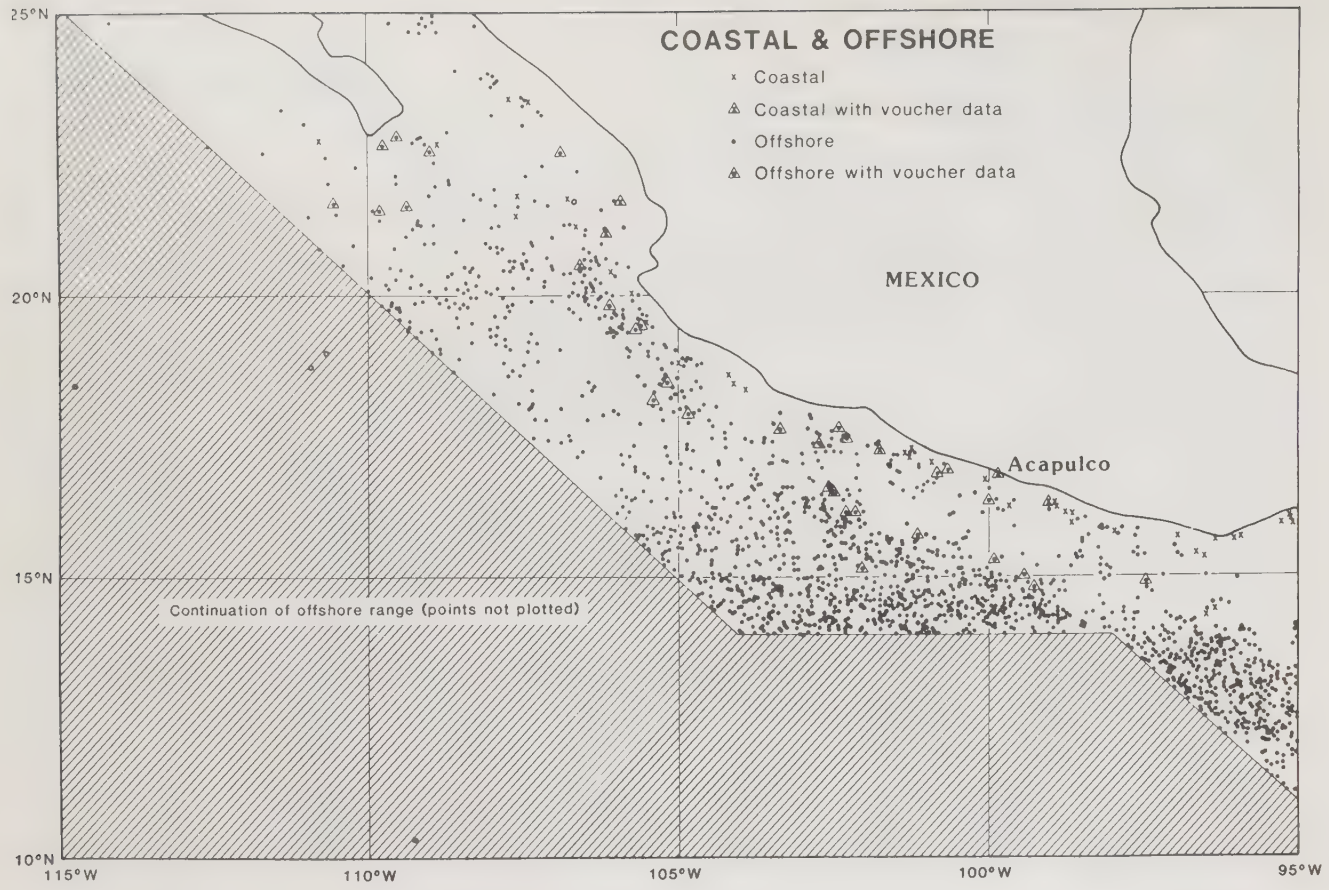
Figure 9.—Records of offshore (dots) and coastal (x's) spotted dolphins in the far-eastern Pacific.

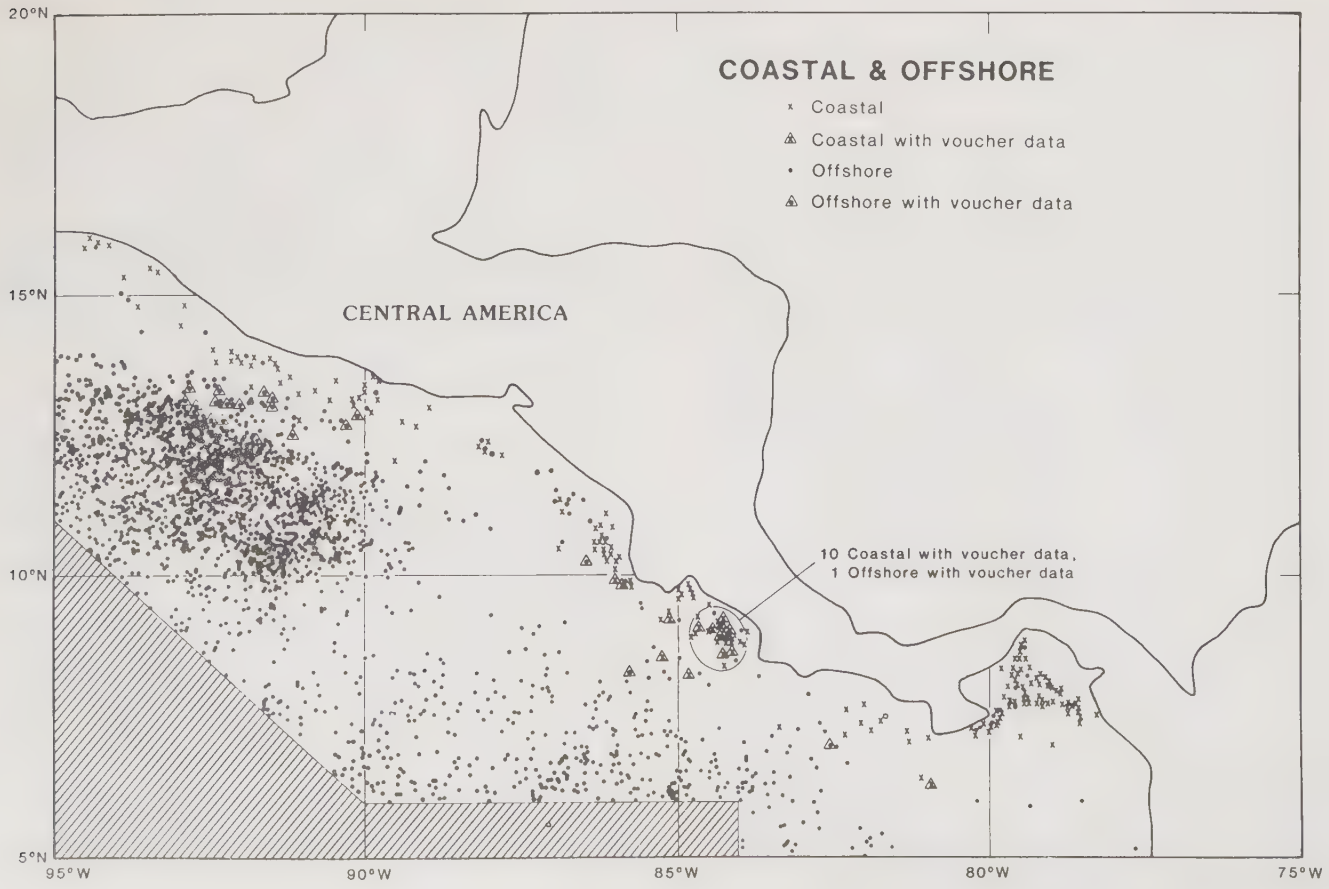
Cocos Island, and Malpelo Island), but there is only one sighting record indicating this. An IATTC technician aboard a commercial seiner approximately 60 nmi off Malpelo Island in 1983 observed a school of 15-30 robust and heavily spotted dolphins that "looked like coastals." The distance from the mainland was approximately 240 nmi. Without more records, it is difficult to say whether the observer just happened to see a few heavily spotted offshore animals (which would be expected under the racial paradigm, given enough observation effort) or the animals around the island are similar to those close to the mainland. We assume the former, pending availability of more information.

Adult male coastal spotted dolphins average about 23 cm longer than offshore males (those north of SOPS '79 north/south boundary—Fig. 1—and east of long. 120°W) and coastal females about 19 cm longer than offshore females (Fig. 12), although there is broad overlap in length. The standard deviations for the coastal samples are appreciably larger than those for the offshore samples (CV = 5.07 and 3.91, respectively). This and the right-skew in the coastal female distribution may mean that some animals classified as "coastal" should have been identified as "offshore," or that intergrades are more common in "coastal" schools than in "offshore" schools, i.e., that the coastal form is more variable, perhaps reflecting proportionately greater introgression of offshore genes into the coastal population than the reverse. Another possible explanation is that coastal females continue to grow longer after attainment of sexual maturity than do offshore females.

The coastal form has been characterized as occurring in relatively "...small groups or schools or (sic) fewer than 100 individuals" (Perrin 1975a:127). In our review of sighting records, we found that while most records were of small groups of animals, there were also several records of very large schools of the coastal form (Table 2). Estimated school sizes ranged to 20,000 animals. Most of the very large schools were seen off Costa Rica, south of Puntarenas (lat. 8°-10°N and long. 83°-85°W), while some were seen off central Mexico (lat. 15°N).

Schnell et al. (footnote 4) concluded that the results of their multivariate analyses of skull data "fully warrant(s) the recognition of the southern *S. attentuata* as a distinct stock." They found the skulls of spotted dolphins from south of the Equator to be, on the average, larger and to have a smaller temporal fossa than those of animals from north of the Equator. They reached the same conclusion from analysis of body-length data; they found the southern animals to be, on the average, shorter than the northern animals. The results of our review of body-length data are the same (Fig. 12). Males from the eastern portion of the SOPS '79 "northern offshore" range were modally about 3.5 cm longer than those from the "southern offshore" range (this difference and others between the offshore samples are statistically significant at $P < 0.001$); the difference for females is 2.5 cm. When the southern sample is compared with the portion of the northern sample from west of long. 120°W, the difference is smaller, 2.0 cm for males and 1.3 cm for females, a result consistent with the finding by


COASTAL & OFFSHORE
Coastal
Coastal with voucher data
Offshore
Offshore with voucher data
MEXICO
Acapulco
Continuation of offshore range (points not plotted)
25°N
20°N
15°N
10°N
115°W
110°W
105°W
100°W
95°W


COASTAL & OFFSHORE
Coastal
Coastal with voucher data
Offshore
Offshore with voucher data
CENTRAL AMERICA
10 Coastal with voucher data,
1 Offshore with voucher data
20°N
15°N
10°N
5°N
95°W
90°W
85°W
80°W
75°W

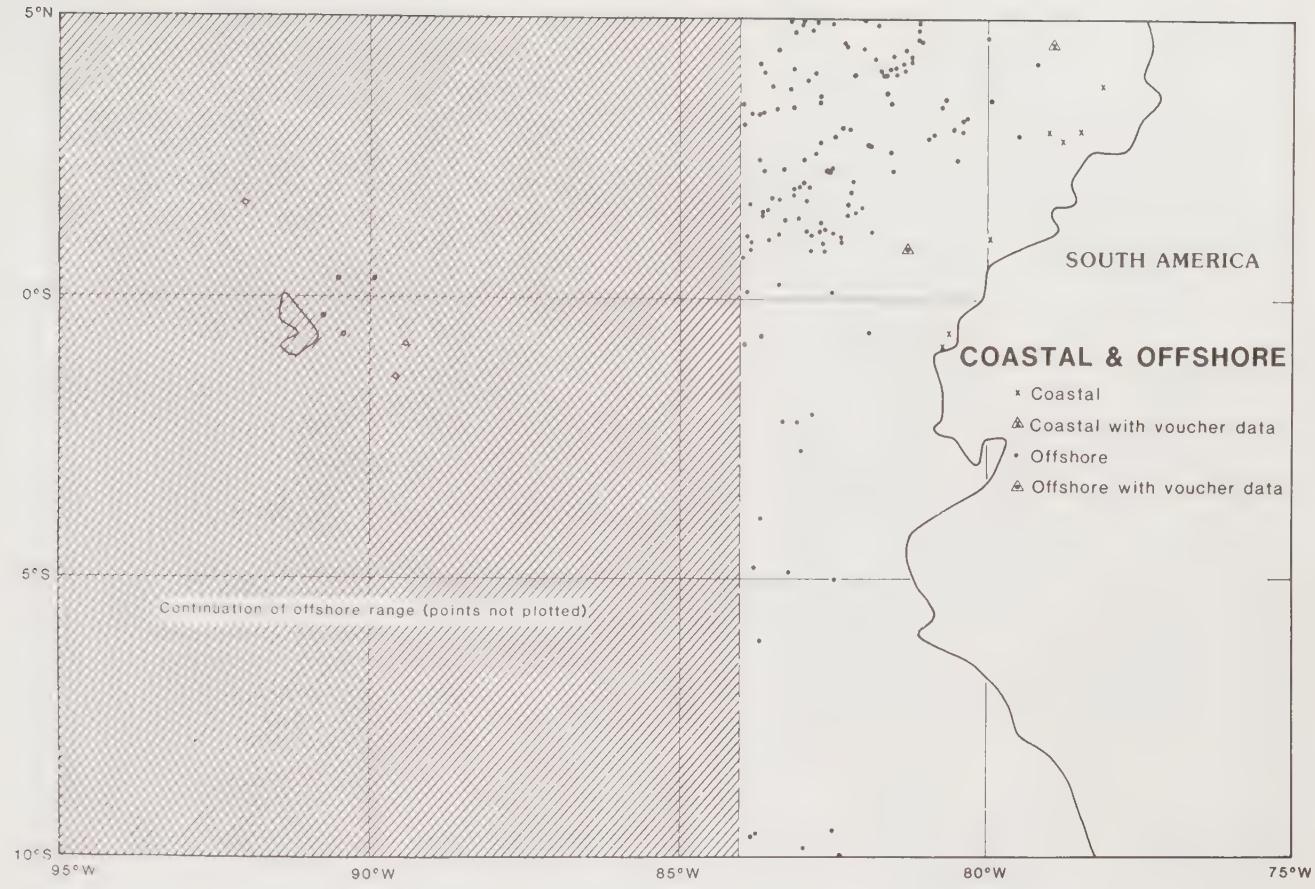


Figure 10.—Records of offshore (small dots) and coastal (x's) spotted dolphins off A) North America (upper left), B) Central America (lower left), and C) South America (above), with records that are supported by photos, measurements, or osteological specimens indicated (triangles).

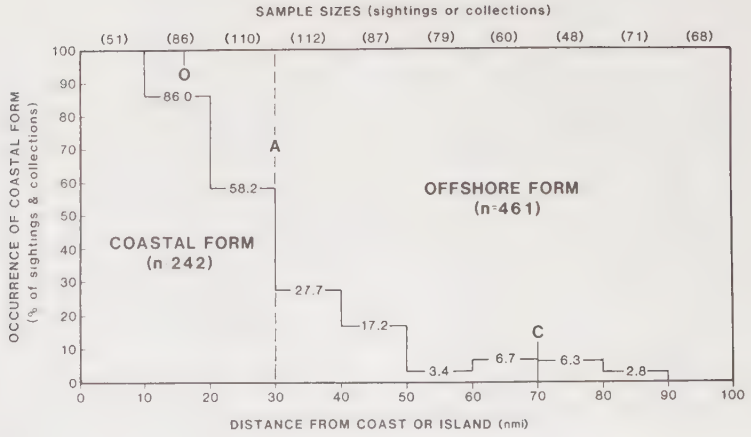


Figure 11.—Relative abundance of records of offshore and coastal spotted dolphins by distance from coast. "C" is most offshore "coastal" record supported by photos, measurements, or osteological specimens; "O" is most inshore "offshore" record with such support. "A" is distance from coast at which the proportion of included records that are offshore equals the proportion of coastal records that are excluded.

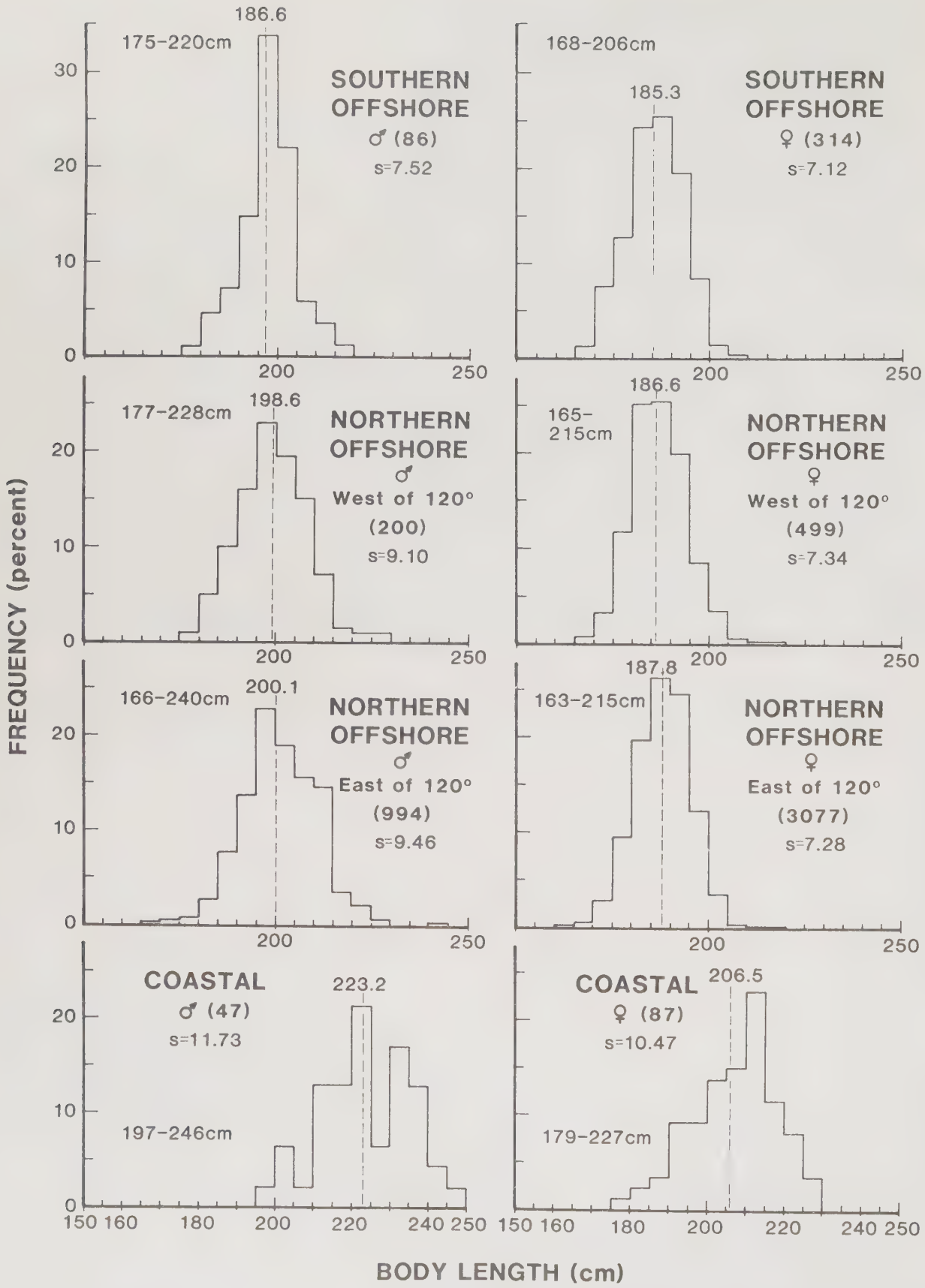


Figure 12.—Frequency distributions, ranges, means, and standard deviations of body length for male and female spotted dolphins, *Stenella attenuata*, from four geographical areas. Sample sizes in parentheses.

Table 2.—Estimated school sizes for sightings of coastal and offshore spotted dolphins within 100 nmi of the coast. Ranges of school sizes in parentheses.

School size (no. of dolphins)	Coastal form		Offshore form	
	n	%	n	%
<100	144 (min. <10)	63.2	59 (min. <10)	13.2
100-1,000	64	28.1	270	60.3
>1,000	20 (max. >20,000)	8.8	119 (max. >20,000)	26.6
Total	228		448	

Schnell et al. (footnote 4) of affinities between southern skulls and a very small sample of skulls from the far-western part of the northern range. The samples used in our body-length comparison covered the geographic range of the species more completely than did the samples of skulls available to Schnell et al. (Fig. 5).

Two additional lines of evidence suggest that the southern animals are smaller than the northern animals: 1) Hohn and Hammond[7] estimated length at birth from northern offshore samples at 85.4 cm. Their estimate from southern offshore samples was 83.2 cm. Their conclusion that the southern form is about 2 cm shorter than the northern form at birth is tentative because of the rather small sample size for the southern form. 2) Average length at attainment of sexual maturity was estimated at 177-180 cm (1974-82) and 175 cm (1973-82) for northern and southern samples, respectively (Barlow in press).

Because both females and males can continue to grow after attaining sexual maturity (Perrin et al. 1976), we considered the possibility that the differences between the northern and southern samples in average lengths of adults reflect not inherent racial difference in size but difference in age structure in the two regions. Samples from the southern region have not been aged, so direct comparison of age structures was not possible. We were able, however, to compare the frequency distributions of ovarian-corpus count for the two samples (Fig. 13). If ovulation rates are assumed to be similar in the two regions, it is clear that the age structures for adult females are not radically different. In any case, the difference is in a direction opposite that which would be expected were the adult southern animals smaller because of being, on the average, younger.

The results of tagging studies (Perrin, Evans, and Holts 1979; Jennings and Stives footnote 5, and unpublished data—J.G. Jennings[8]) indicate considerable east-west movement within the northern offshore range. Of 206 tag recoveries or resights of tags or fin notches, 9 indicated movement from east to west of the 120th meridian; three involved movement of at least 1,300 nmi, over a period of 9-10 mo. While this inference of long east-west movement must remain provisional (none of the 3 cases involved the actual recovery of a tag), when it is considered in the context of a possible east-west cline in morphology (body-length, coloration, and skull measurements), it suggests that such morphological differentiation is maintained despite at least temporary long-range movements of individuals and perhaps schools. One tag released north of lat. 10°N was resighted by a tuna-seiner crewman (but

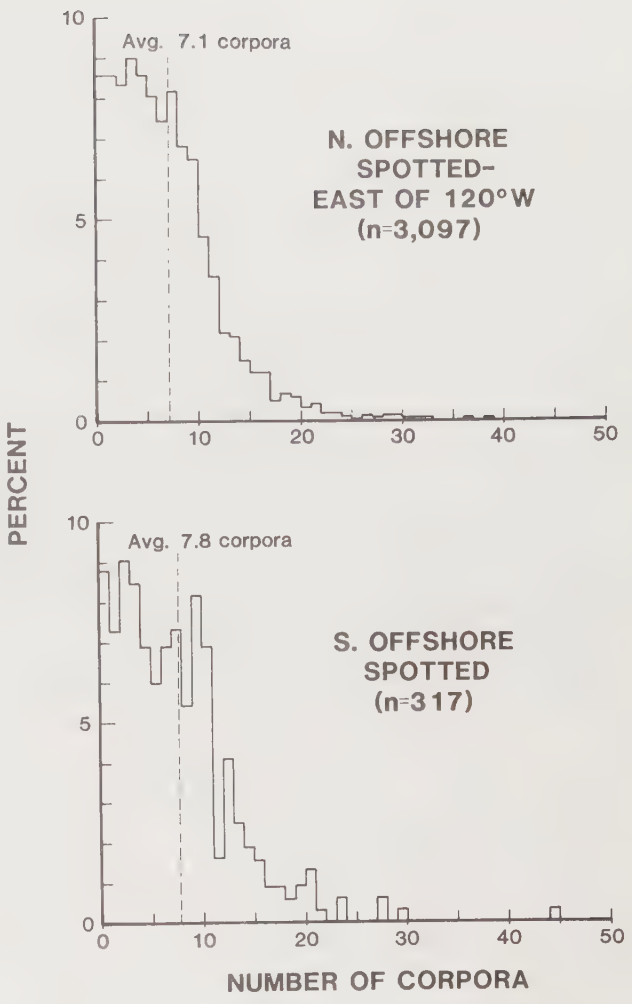


Figure 13.—Frequency distributions of ovarian-corpus count for northern and southern offshore samples of adult female spotted dolphins.

not recovered) at lat. 10°37'S, some 4-5 mo later. This result, if confirmed, would suggest that the apparent north-south morphological differences may actually reflect a clinal situation similar to that (east-west) which may exist in the northern offshore portion of the range, rather than a substantial separation of populations north and south of the Equator.

The results of a study of breeding seasonality (Barlow 1984) show very different distributions of birth dates in southern and northern offshore spotted dolphins (SOPS '79 boundaries). In the south the single calving season is quite short, March to May, whereas in the north there are two diffuse breeding peaks, in the spring and in the autumn. Barlow stratified the northern sample into two subsamples, from lat. 0°-5°N and from north of lat. 5°N, and found an intermediate pattern in the equatorial stratum of a single but diffuse calving peak from March to June, statistically different from the patterns both to the south and the north. He concluded that these results support the view of a separate population south of the Equator but that the transition from a diffuse bimodal breeding pattern in the north to a single sharp peak in the south may not be abrupt. He offered two possible explanations for the apparent patterns: 1) if seasonality in reproduction is determined by the timing of oceanographic or trophic factors, the dif-

[7]Hohn, A. A., and P. S. Hammond. 1983. Growth in the first year of the offshore spotted dolphin, *Stenella attenuata*, in the eastern tropical Pacific. Southwest Fisheries Center Admin. Rep. LJ-83-08, 33 p.

[8]J. G. Jennings, Fishery Biologist, Southwest Fisheries Center La Jolla Laboratory, National Marine Fisheries Service, NOAA, P.O. Box 271, La Jolla, CA 92038, pers. commun. January 1983.

ference could reflect geographical change in the timing of the environmental determinants, or 2) the area between lat. 0° and 5°N could represent an area where two populations can occur, with the apparent distribution of birthdates actually being a composite of two different distributions. He noted that if a previously noted relative hiatus in sightings in the vicinity of the Equator (Perrin, Sloan, and Henderson 1979) is real, the latter explanation would be the least likely. The band of low density of sightings for 2°-3° south of the Equator is still present (Perrin et al. 1983) but not as well defined as previously.

Hohn and Hammond (footnote 7) have confirmed Barlow's results with modal-progression analysis of monthly distributions of length (after adjusting for use of different growth curves in the two studies), finding birth of two annual seasonal cohorts in the north but only one in the south. They also found a pattern of variation within the northern range; data from the far west and from along the Equator do not fit well with the pattern in data from the more easterly and northerly major part of the range. They concluded that while spotted dolphins may have different calving seasons depending on area of capture, this seasonality is probably "not actually a function of area but of schools or groups of schools which tend to inhabit different areas with different environmental conditions."

Resolution of the nature of the east-west and north-south variation must await study of more material from west of long. 120°W and from near the Equator (see also the discussion below on origins of the geographical forms).

Stenella longirostris

In our review of records within 50 nmi of the coast, we found only 33 convincing "Costa Rican" records, all south of the Gulf of Tehuantepec (Fig. 14) and north of the Bay of Panama. Of these, 16 were supported by photos or measurements of specimens (Fig. 15, Table 3). We found no coastal records of eastern spinner dolphins with such support below the Gulf of Tehuantepec and only six unsupported records there. It appears that the eastern spinner dolphin is largely, or possibly totally, replaced on the coast below about lat. 15°N by the larger, longer beaked Costa Rican form. We ascribe the relatively small number of convincing records of either form to the difficulty of estimating size of animals at sea; the two forms are not known to differ in coloration. The sample of body lengths for the Costa Rican form taken directly from specimens is very small (Fig. 16), but it is probable that modal adult length differs from that of the eastern form by about 30-40 cm in both sexes. A very large sample of photogrammetric lengths for both forms supports this conclusion (unpubl. data, M. D. Scott).

We found several well-supported records of the eastern form outside the SOPS '79 boundary (Fig. 14); the range of this form

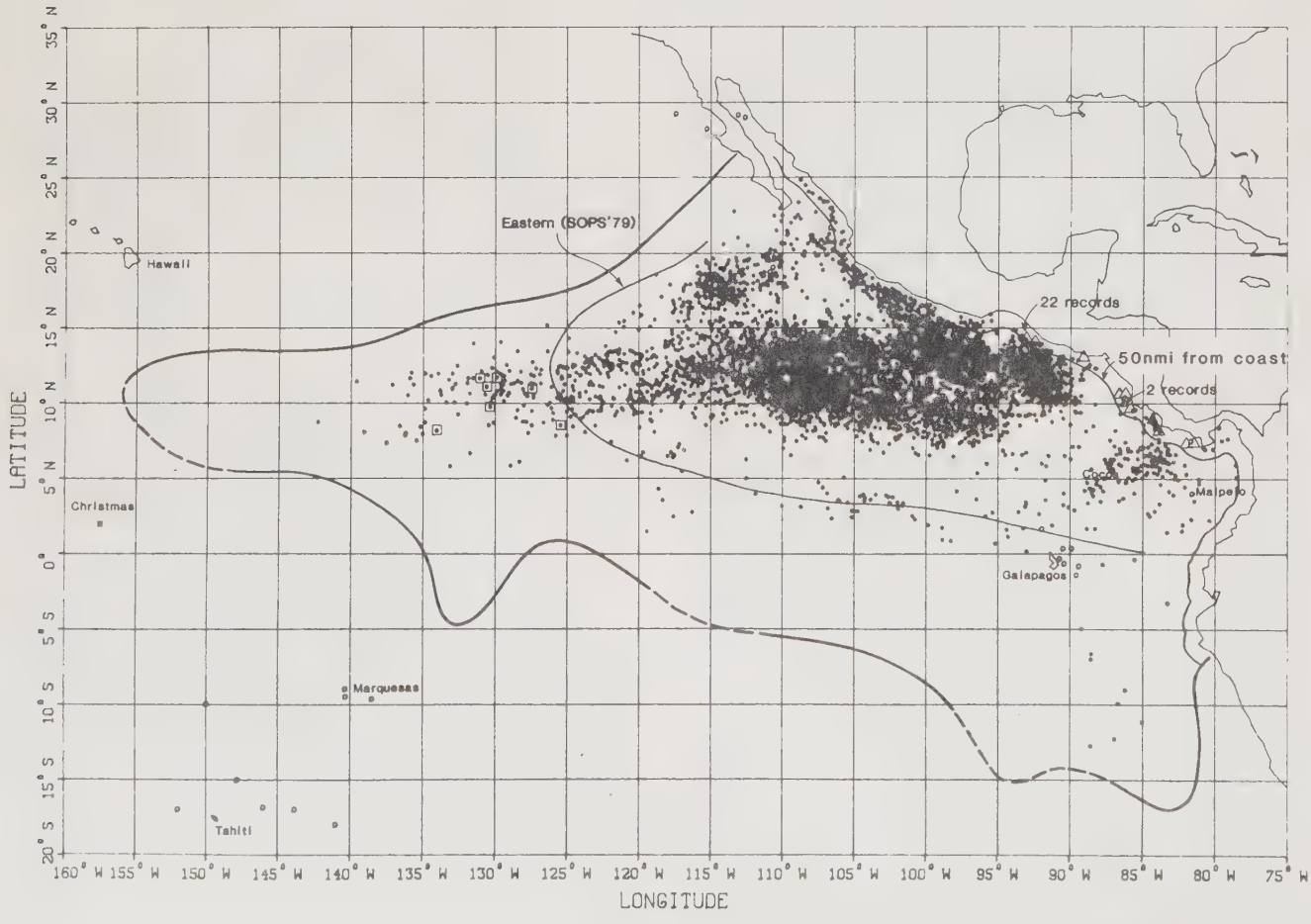


Figure 14.—Distribution of eastern and Costa Rican spinner dolphins in the eastern tropical Pacific, showing records outlying the SOPS '79 boundary for the eastern form. Outlying records enclosed in squares are supported by specimen data.

Table 3.—Records of Costa Rican and eastern forms of *Stenella longirostris* within 50 nmi of the coast (or a coastal island), north and south of Gulf of Tehuantepec (~ lat. 15°N). Number of records supported by photos, body-length data, or skull specimens in parentheses.

Gulf of Tehuantepec	Distance from coast (nmi)	Costa Rican form (records)	Eastern form (records)	Total
North of Gulf	0- 9	0	0	0
	10-19	0	8(1)	8(1)
	20-29	0	13(2)	13(2)
	30-39	0	7(0)	7(0)
	40-49	0	11(4)	11(4)
	Subtotal	0	39(7)	39(7)
South of Gulf	0- 9	3(2)	0	3(2)
	10-19	1(1)	1(0)	2(1)
	20-29	7(3)	5(0)	12(3)
	30-39	[1]19(9)	0	[1]19(9)
	40-49	3(1)	1(0)	4(1)
	Subtotal	33(16)	7(0)	40(16)
	Total	33(16)	46(7)	79(23)

[1]Includes 17 sightings made in a small area off southern Mexico during an aerial photogrammetric experiment by the Inter-American Tropical Tuna Commission in 1980 (see Fig. 15). Other intervals contain records from this source as follows: 20-29 nmi, 6; 40-49 nmi, 1 (all Costa Rican).

extends farther to the west than previously documented, to at least long. 134°W, albeit in apparent very low density relative to that of the whitebelly form (Fig. 17). We found only one well-supported record of the whitebelly form to the east of the SOPS '79 boundary (Fig. 17). We attribute the large number of unsupported whitebelly sightings to the identification difficulties discussed in the Materials and Methods section and believe that many of them probably represent sightings of misidentified eastern spinners. In any case, the inshore density of whitebelly spinner sightings is very low relative to that of the eastern form (Fig. 14).

Rather than draw boundaries around what are believed to be the major ranges of the two forms, as has been done in the past, we instead present a summary of relative frequency of records by 5° square (Fig. 18; values in Appendix 2). The sample sizes on the fringe of the continous range of the species in the eastern tropical Pacific are small, but those in the major zone of overlap are very large, and the proportions likely reflect the true relative abundances of schools of the two forms. As discussed above, the real levels of whitebelly-spinner-dolphin records in the northeastern reaches of the eastern range are likely lower than indicated, e.g., we believe that the anomalously high proportion in the square at

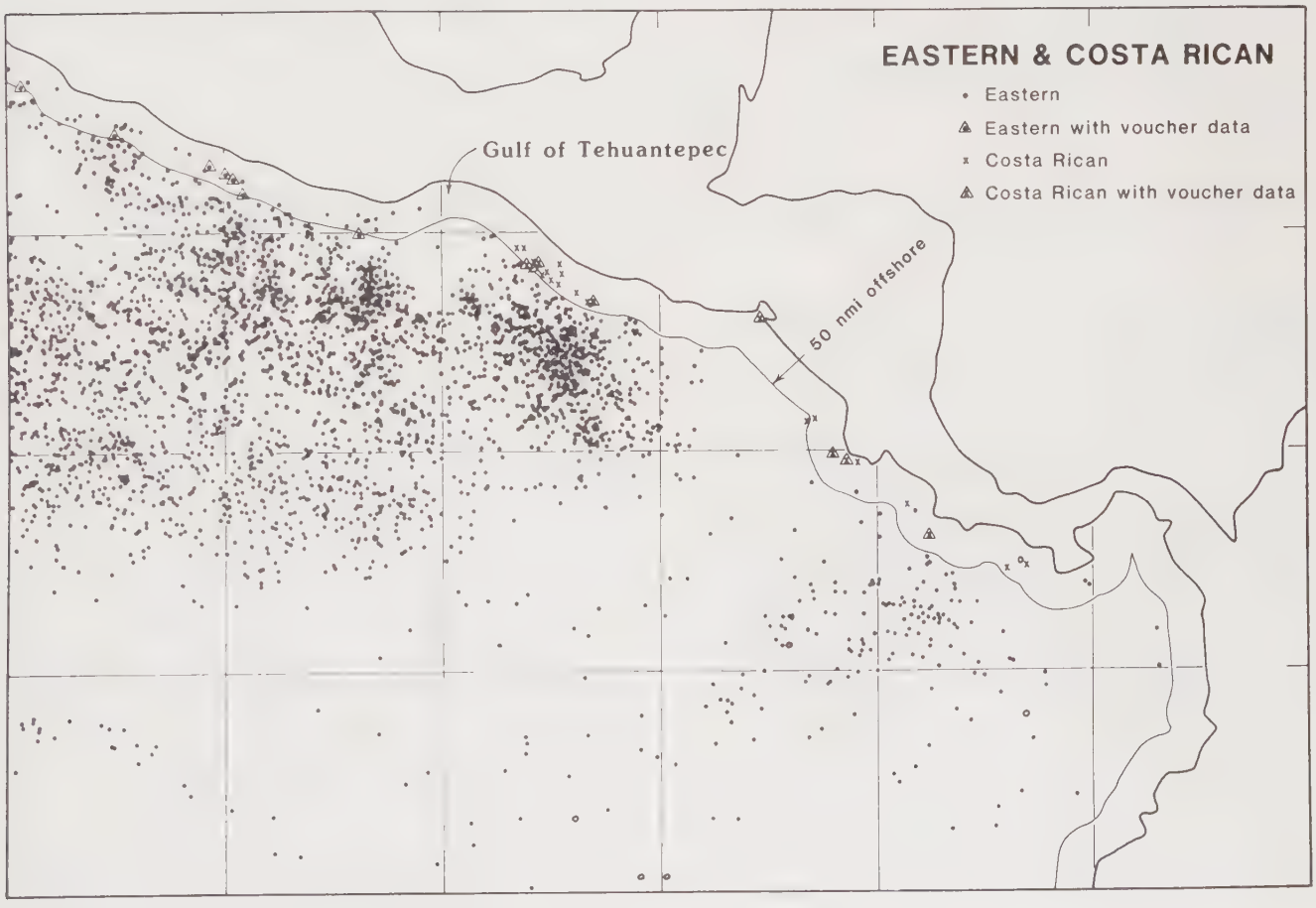


Figure 15.—Distribution of eastern (dots) and Costa Rican (x's) spinner dolphins off Central America, with records inside 50 nmi supported by photos, measurements, or osteological specimens indicated (triangles).

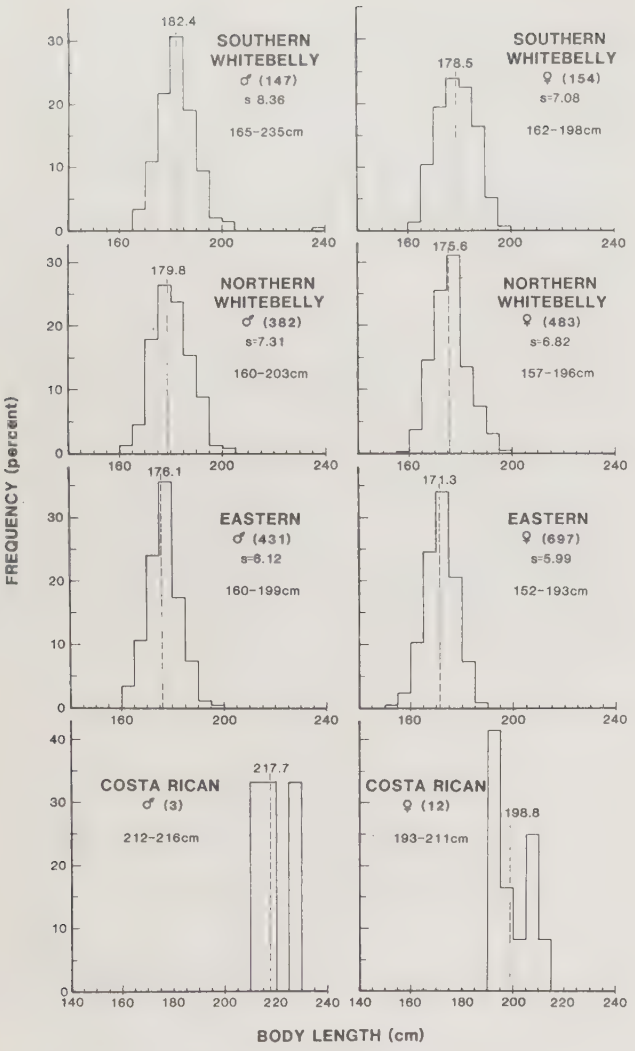


Figure 16.—Frequency distributions, ranges, means, and standard deviations of body length in samples of adult specimens of *Stenella longirostris* of four stocks. Sample sizes in parentheses.

the tip of Baja California may be the result of unfamiliarity with the two kinds of spinner dolphins by south-bound first-time observers.

Eastern spinner dolphins are, on the average, about 3-4 cm smaller (significant at $P < 0.001$) than (northern) whitebelly spinner dolphins (Fig. 16). The length-frequency distributions for the two forms are very similar in shape, and the variances are small compared with those for other samples examined here, suggesting that the two populations are well delineated and accurately represented by the samples.

Schnell et al. (footnote 4) found "marked differentiation of a southern form from populations to the north" based on multivariate analysis of skull measurements. They found skulls from the south to be larger, with a proportionately larger temporal fossa, than skulls from the north, a situation exactly the opposite of that found in *S. attenuata* (smaller skulls, with larger fossa, in the south). As was the case of *S. attenuata*, they noted morphological affinities, in some of the analyses, between southern specimens and those from west of long. 120°W. They also found southern spinners to be longer than northern specimens. However, they did not distinguish between the eastern and whitebelly color forms. Our comparison of body length for northern and southern whitebelly spinner dolphins using the SOPS '79 ranges showed a difference of about 2-3 cm (significant at $P < 0.01$) in males and females (Fig. 15). No new information is available on color pattern of the southern spinner dolphins beyond that given in Perrin, Sloan, and Henderson (1979).

Because of the possibility that the difference in average body length could be caused by a difference in age structure (i.e., relatively more younger and smaller adult females in the northern region), we examined the frequency distributions of ovarian-corpus count for the two samples (Fig. 19), again assuming similar ovulation rates. The distributions do indeed differ, with a higher proportion having fewer than three corpora in the northern sample than in the southern sample. This may reflect differing age structures or differing ovulation rates; resolution of the question will require comparison of aged samples (not yet available for the southern form).

Tag returns for *S. longirostris* from the eastern tropical Pacific have been few and suggest less extensive movement than do those for *S. attenuata* (Perrin, Evans, and Holts 1979). There has been one sighting (by a yachtsman) of a tagged animal in the Marquesas (a spaghetti tag of unspecified type; J. G. Jennings footnote 8), where nine spinner dolphins were tagged in 1976 (Table 1). There have been no tag returns indicating movement across the Equator or between the far-eastern and far-western parts of the eastern tropical Pacific above the Equator.

Barlow (in press a) found a single sharp seasonal breeding peak in the eastern spinner dolphin and at least two modes in the northern whitebelly spinner dolphin. He also found a regional difference in timing of the peak in the eastern spinner dolphin, with offshore animals calving earlier in the year than inshore animals. He noted that distributional studies indicated that there are inshore and offshore population centers for eastern spinner dolphins with a decreased density of sightings in between (Fig. 14 and Au et al. footnote 3) and suggested that a further subdivision of the eastern spinner into two populations/stocks would be meaningful. He did not examine seasonality in spinner dolphins south of the Equator.

Stenella coeruleoalba

Very little new information is available for this species. Delineation of the three tropical stocks was based on apparent latitudinal gaps in distribution, pending availability of adequate series of morphometric data (Smith 1983; Au et al. footnote 3). The band of relatively low density of sightings between lat. 10° and 15°N is apparent in the data (Fig. 20), but the distribution now appears relatively continuous south of lat. 15°N and east of about long. 115°W, with a region of lower apparent density around the Galapagos Islands (which may only reflect the lesser sighting effort there—Perrin et al. 1983, Fig. 1). It would seem that there is now little or no justification for dividing the animals in this area (south of lat. 15°N and east of long. 115°W) into two stocks based on distribution data alone. The same applies to the eastern and western concentrations within the "central tropical" range; sighting effort has been relatively lower in the region between them. Only the low-density band between lat. 10° and 15°N at this point can be said with some confidence to be real. There is a 200-300 nmi wide swath extending northeastward from long. 105°W where no striped dolphins have been sighted despite extremely high levels of sighting effort. We conclude that direct interchange between the population centers to the north and south probably occurs so seldom as to be negligible. In the region im-

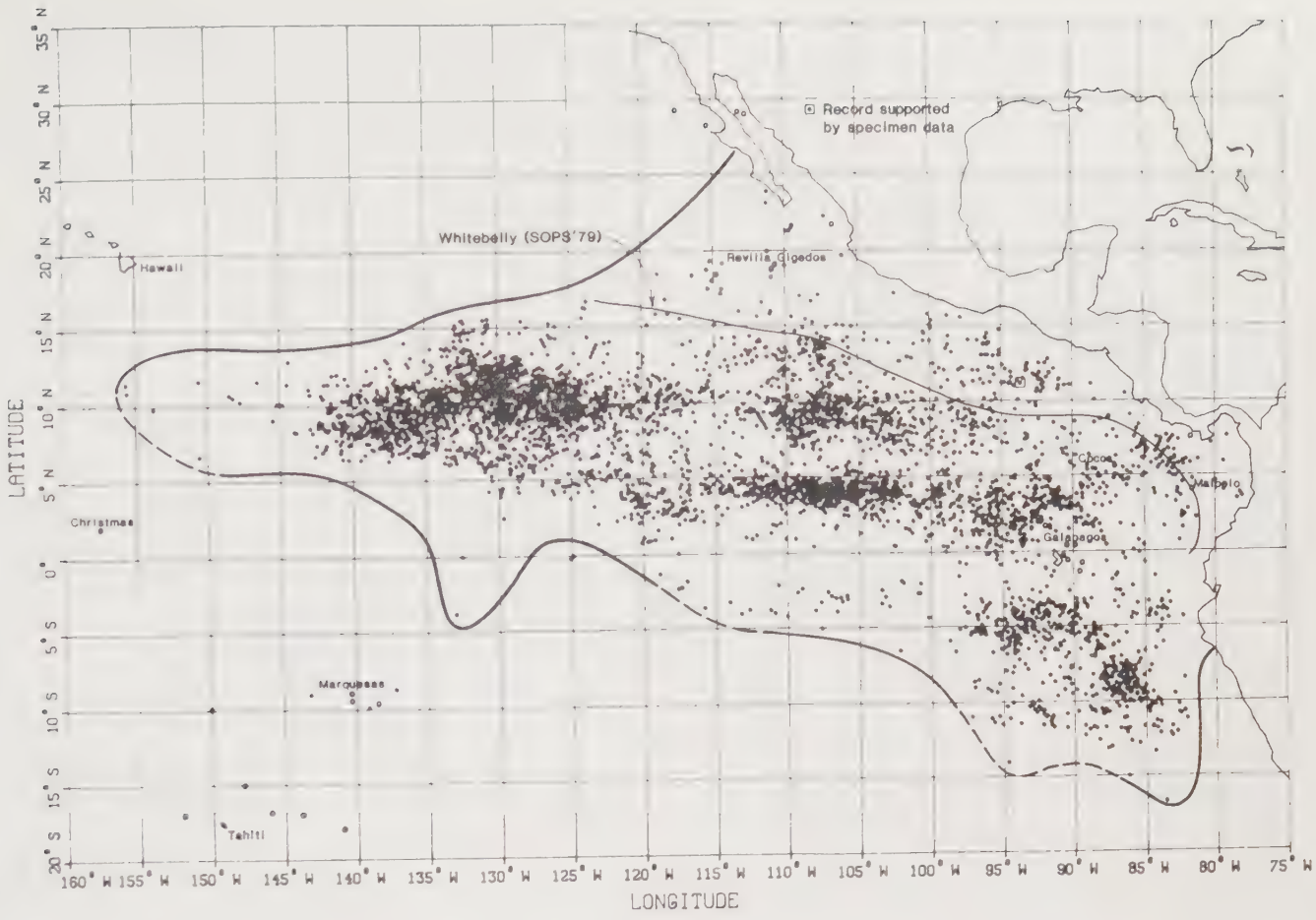


Figure 17.—Distribution of whitebelly spinner dolphins (northern and southern) in the eastern Pacific, showing records east of the SOPS '79 boundary. Record enclosed in square is supported by specimen data.

mediately to the west (between about lat. 10° and 15°N and long. 105° to 120°W), where sighting effort has also been extremely heavy, there are only a few records of the species; the density here is apparently also very low.

In the area north of lat. 25°N, where sighting effort has been extremely heavy to at least lat. 31°N, scattered sightings of striped dolphins have continued to accumulate (Perrin et al. 1983), but it would appear that the animal occurs rarely in this warm-temperate part of its range in the eastern Pacific. It seems to us unlikely that this represents a separate population center. Similarly, the deduction of the existence of a "southern temperate" stock south of lat. 10°S is probably also not justified.

The very limited adult body-length data (most of the animals killed have been juveniles) do not suggest a modal difference in length between animals from the northern and central tropical ranges (Fig. 21). Only one adult (a 204 cm female) from the southern tropical range has been measured.

Delphinus delphis

Although "Baja neritic" and "northern tropical" stocks were defined by Evans (1975, 1982) based on morphology and color patterns (Fig. 4), these have been pooled in assessment and management (Holt and Powers 1982; Smith 1983). Common dolphins sampled in the fishery and tropical sightings have been identified only as "*Delphinus delphis*" and allocated by position to the "northern tropical" (3°N-10°S) latitudinal management units. This pooling is evident in the "northern tropical" (between lat. 15° and 28°N), "central tropical" (lat. 3°-15°N), or "southern tropical" body-length data (Fig. 22); the Baja neritic form is about 30 cm longer than the northern tropical form (Evans 1982). The animals included in the "northern tropical" sample came from two areas: Baja California (Squares 168, 169, and 189 in Figure 8), and off southern Mexico (Square 146). Those from north of Magdalena Bay (Square 189) appear from their lengths (shaded portions of histograms in Figure 20) to have been of the Baja neritic form, whereas those from south of Magdalena Bay and around Cabo San Lucas into the Gulf of California (Squares 168 and 169 in Figure 8) appear to have been of the short-beaked northern tropical form. Evans (1982) showed the range of the Baja neritic form as including the Gulf of California. Some of the Baja neritic common dolphins on the outer coast were taken more than 50 nmi offshore, and some of the short-beaked "offshore" animals were captured within 10 nmi of the coast (Table 4). When this is considered in the context of the pooled distribution data (Fig. 23), it is clear that common dolphins off Baja California cannot be identified to stock on the basis of an inshore-offshore criterion alone. The two forms are, however, fairly easily identi-

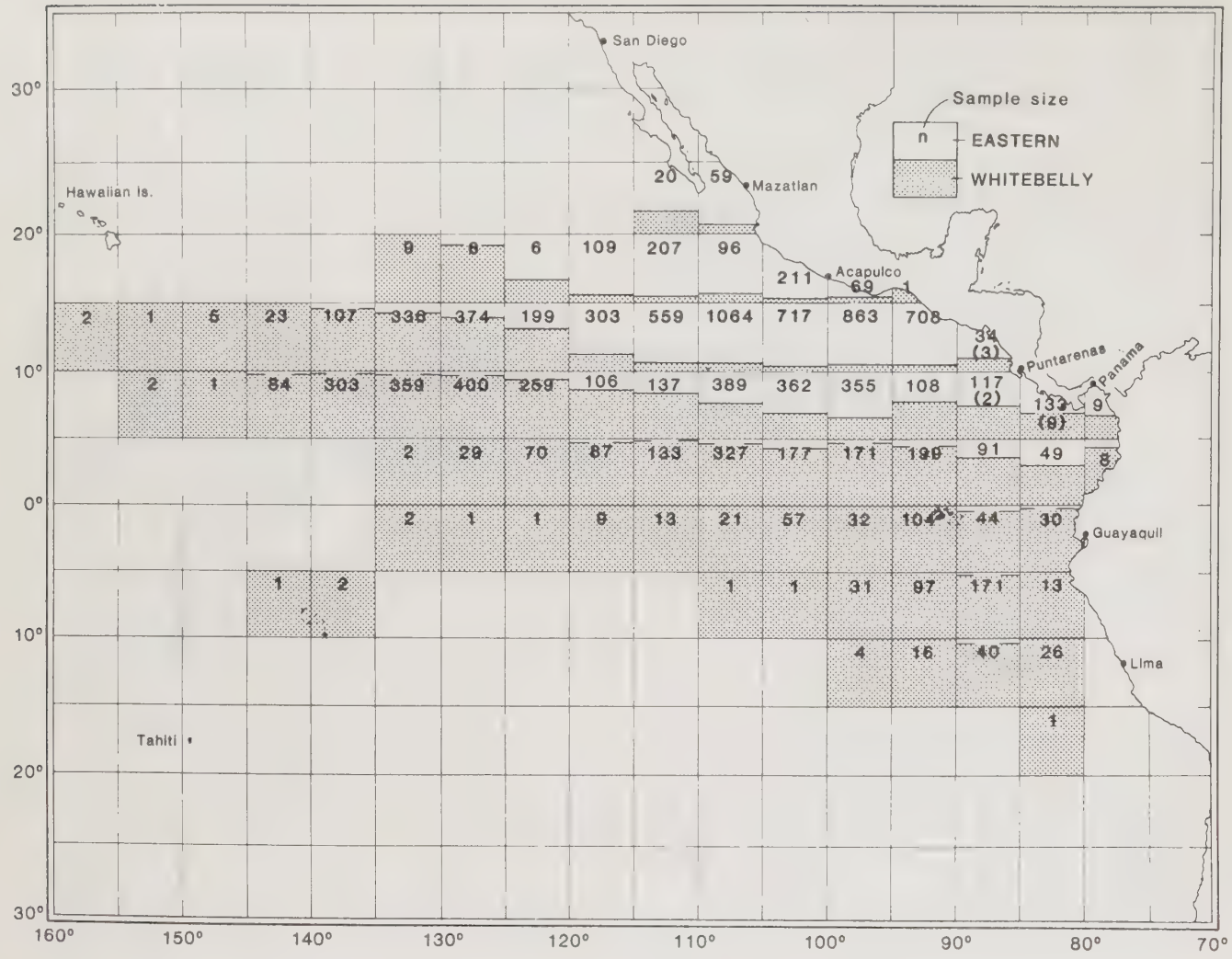


Figure 18.—Racial composition by 5° square of sightings of *Stenella longirostris* identified to geographical race. Open areas of squares represent eastern form (and, for four squares, Costa Rican); shaded areas represent whitebelly form (northern and southern). Sample size given for each square. Number of Costa Rican records in parentheses.

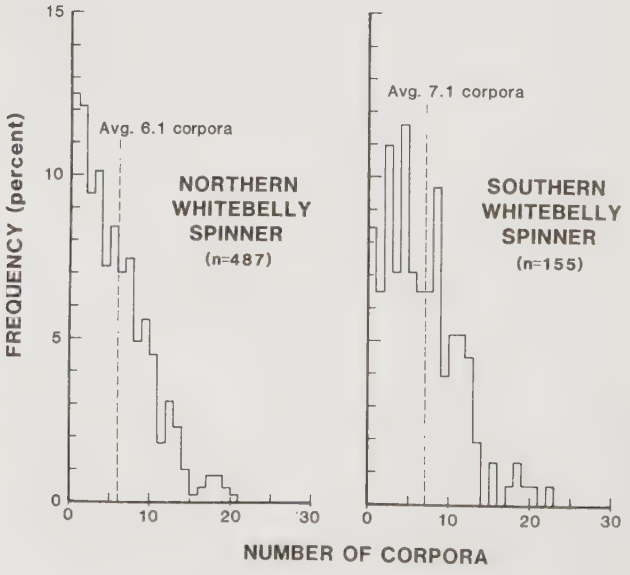


Figure 19.—Frequency distributions of ovarian-corpus counts in northern and southern samples of adult female spotted dolphins.

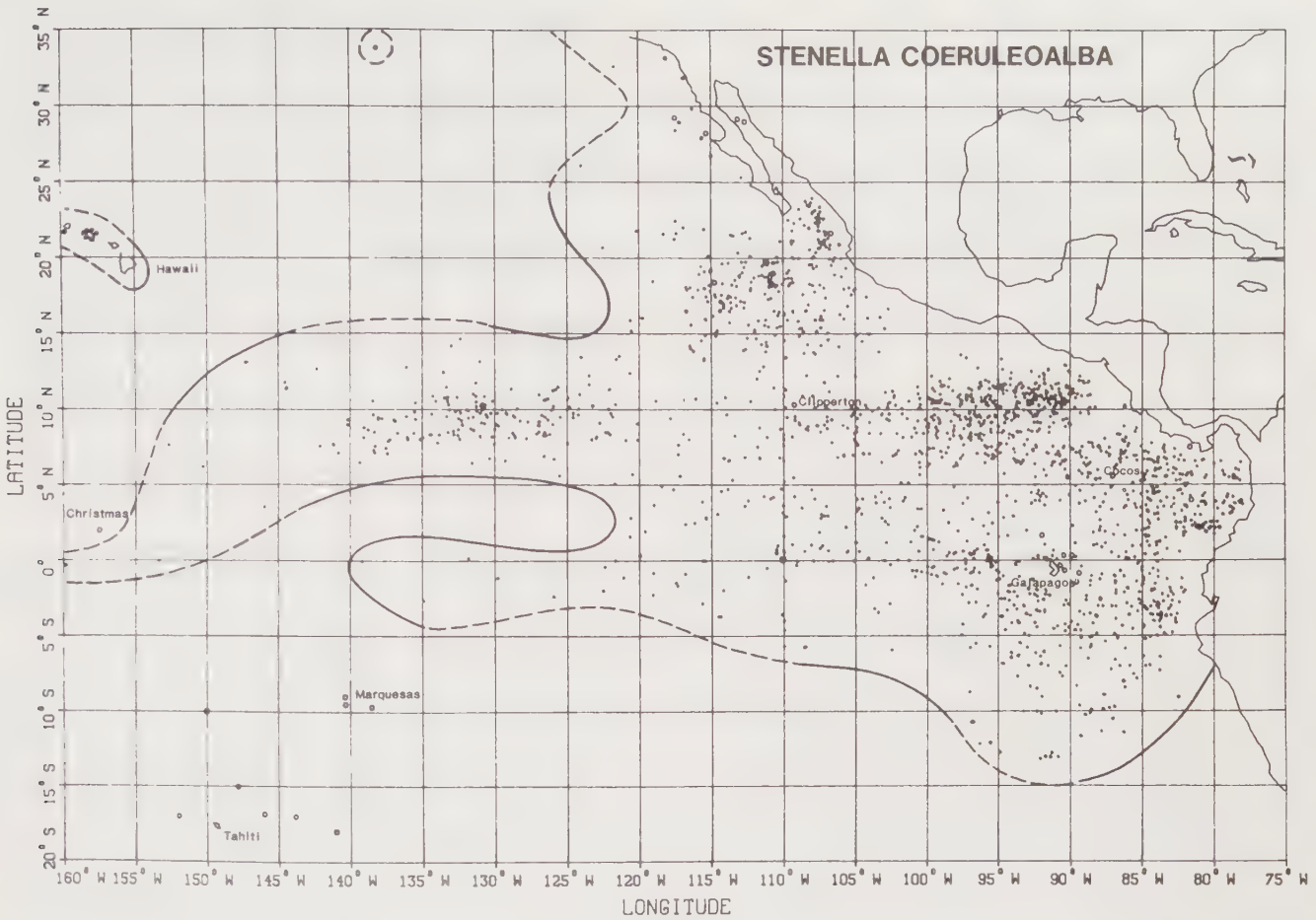


Figure 20.—Records of *Stenella coeruleoalba* in the eastern Pacific. Boundary from Perrin et al. (1983).

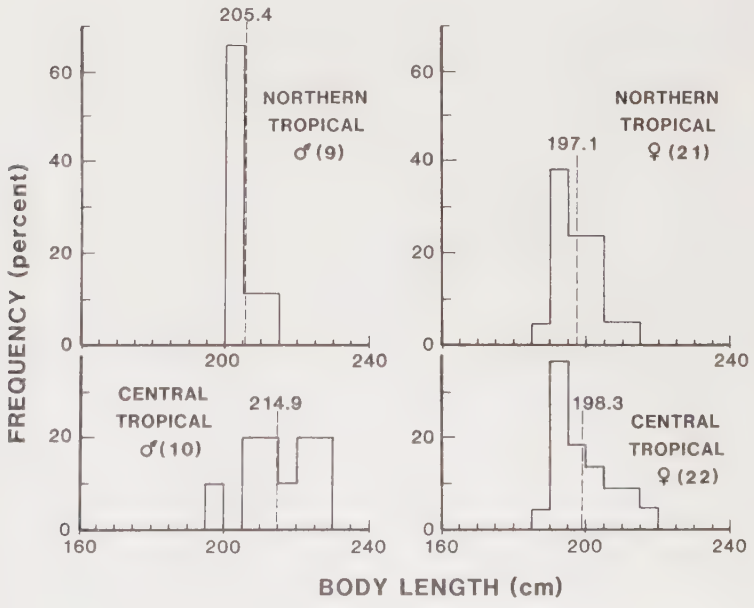


Figure 21.—Length-frequency distribution and means of body length for nothern tropical and central tropical adult males and females of *Stenella coeruleoalba*. Sample sizes in parentheses.

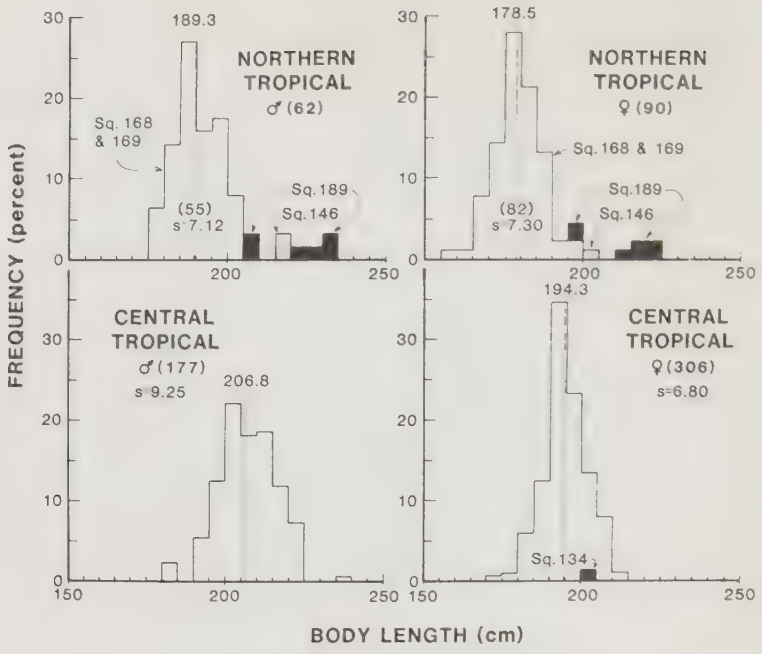


Figure 22.—Frequency distributions, ranges, means and standard deviations of length in two stocks of *Delphinus delphis*. Sample sizes in parentheses.

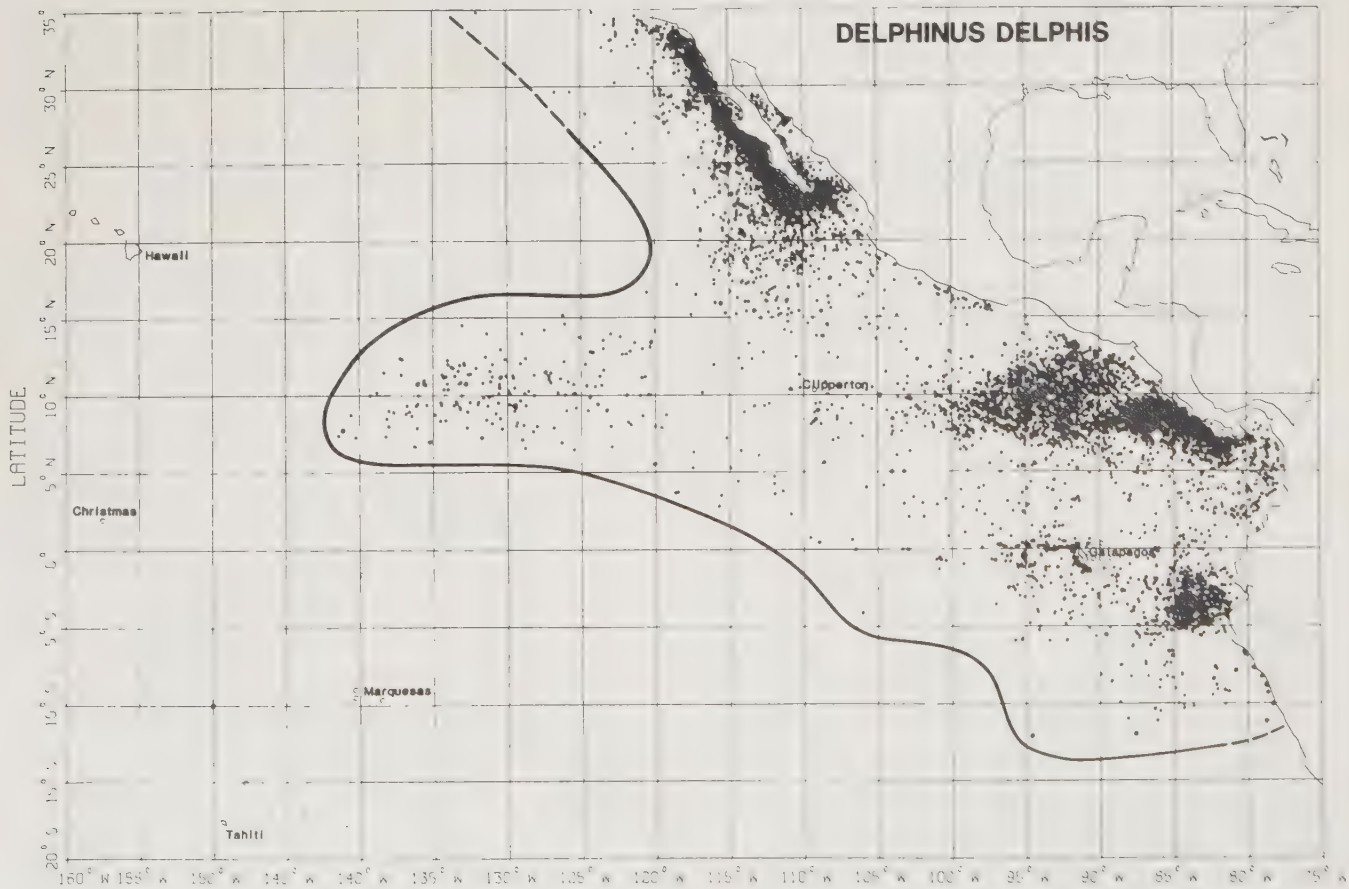


Figure 23.—Records of *Delphinus delphis* in the eastern tropical Pacific. Boundary from Perrin et al. (1983).

Table 4.—Distances from coast of specimen records of *Delphinus delphis* in Square 189 (Baja neritic form; north of lat. 25°N) and Squares 168-169 (northern tropical form; south of lat. 25°N). Most offshore record of Baja neritic at 51 nmi; most inshore northern tropical at 51 nmi. See Figure 8 for locations of squares and Figure 22 for specimen data.

Distance from coast (nmi)	Records	
	Baja neritic in Square 189 (no.)	Northern tropical in Squares 168 & 169 (no.)
0- 9		1
10-19	1	7
20-29	2	7
30-39	2	10
40-49	4	12
50-59	1	12
60-69		8
70-79		9
80-89		4
90-99		6
Total	10	76

fied at sea by size, shape, and coloration (Leatherwood et al. 1982).

In addition to the specimens indicated in Figures 8 and 2, there were 21 animals measured from Square 189 for which gonadal material was not collected that would allow them to be classified as adult or immature. The lengths of 11 males were 153, 164, 195, 208, 218, 225(2), 227, 228, 230, and 236 cm. The lengths of 10 females were 181, 197(2), 199, 205, 206(2), 209, 213, and 215 cm. These lengths more likely belong to the same frequency distributions as the adult animals from Square 189 than to those of the animals from Squares 168 and 169 just to the south. Therefore, maximum length of the Baja neritic form can be assumed to be at least 236 cm.

The sample from off the state of Guerrero in southern Mexico (Square 146) is too small (2 males and 3 females, cross-hatched in Figure 22) to allow a firm conclusion to be made, but it apparently does not belong to the same distribution as the animals from Squares 168 and 169.

Evans initially (1975) did not subdivide the short-beaked "temperate-subtropical" animals north of lat. 20°N into temperate and tropical stocks. He later (1982) defined a "northern" stock in the eastern tropical Pacific extending from about lat. 16°-18°N to just below Cedros island (about lat. 28°N) but did not delineate a "temperate" stock to the north. The 1979 assessment used "northern temperate" and "northern tropical" management units divided at lat. 28°N. The very extensive distribution data do not now suggest a gap or transition of any sort down the entire length of Baja California, and the "northern tropical" body-length data (Fig. 22) accord precisely with Evans' (1975) pooled sample of all short-beaked "temperate-subtropical" animals from north of lat. 20°N. Thus no evidence exists to support dividing the short-beaked common dolphins at lat. 28°N.

Evans (1975) found short-beaked common dolphins from south of lat. 15°N ("central tropical") to be modally longer than those from north of lat. 20°N as well as differing from them in skull features and possibly in color pattern. The present larger sample of central-tropical length data (177 males and 306 females, vs. 40 males and 48 females in Evans (1975)) confirms this; the difference is approximately 18 cm in males and 16 cm in females. With the exception of the local concentration of records off southern Mexico between about long. 97° and 103°W (Fig. 23), the central-tropical concentration (centered around lat. 8°-10°N) is separated from the northern-tropical concentration by an 800 nmi wide zone in which sighting effort has been heavy and sightings of common dolphins rare (only a dozen or so, compared with several thousand sightings of other species). This separation and the morphological differences speak strongly for treating the two populations as separate stocks. The coastal animals from between long. 97° and 103°W are problematical; their lengths do not accord well with the distributions for either the "northern tropical" or the "central tropical" samples, although they fit best with the latter. Determination of their affinities with any confidence must await study of osteological material and accumulation of more length data. Provisionally, they could be included in the central-tropical unit. They may prove to comprise a separate population, however, and it would be equally reasonable to treat them separately at this time.

Length was available for only one (female) common dolphin from the far-western portion of the central-tropical range (Square 134 in Figure 8); it is within the central-tropical range of length (shaded in Figure 22). The number of records of the species from west of long. 120°W is small (Fig. 23), despite heavy sighting effort (Perrin et al. 1983), and the distances separating the area from the denser population centers to the east are large. Determination of affinities must await more information.

Evans (1975, 1982) did not examine material from south of lat. 3°N, the "southern tropical" range. Length data are available for only 6 adults (females: 180, 182, 188, 189, 194, and 198 cm). These accord about equally well with the length distributions for the central tropical and the northern tropical samples (Fig. 22). Since the distribution of the common dolphin in this area exhibits a largely reciprocal relationship with that of the spotted and spinner dolphins, being abundant in regions likely to have lower sea-surface temperatures (near the Galapagos Islands and near the coast of Peru at lat. 0°-5°S) than do the areas where those species are abundant (Perrin et al. 1983), it is possible that the concentration near and below the Equator represents a temperate-tropical stock analogous to the short-beaked northern temperate-tropical stock. There is fairly good separation from the central-tropical center by a band of heavy sighting effort and few sightings between lat. 0° and 5°N.

ORIGINS OF THE GEOGRAPHICAL FORMS

The results for *Stenella* spp. suggest that a concept of radially patterned geographical variation in the eastern tropical Pacific may be more appropriate than the primarily latitudinal approach that has held sway to date. The radial pattern also meshes better with our developing understanding of the ecology of pelagic dolphins in the eastern tropical Pacific. Perrin (in press) has suggested that the variation between central Pacific and eastern Pacific races of *Stenella attenuata* and *S. longirostris* may actually constitute ecological character displacement between the two species in the eastern tropical Pacific, where they school and feed together. (They school and feed separately elsewhere.) Under this hypothesis, the animals forage together because of mutual advantage gained in finding prey or in avoiding predators[9] in the special conditions of the oceanographically anomalous eastern tropical Pacific,[10] and their divergence in coloration, tooth size, jaw

[9]Norris and Dohl (1980) have suggested that Eastern Tropical Pacific spinner dolphins may use the shelter of spotted dolphin schools as a surrogate for the shallow bays in which they spend their daytime resting hours in the central Pacific.

[10]The eastern Pacific is peculiar in having a relatively thin, warm mixed layer (50 m thick) above a stable steep thermocline and a thick oxygen minimum layer. This establishes an effective shallow habitat much like the nearshore habitat in other tropical waters (see Perrin et al. 1976 and Au et al. footnote 3).

muscles, etc. reflects divergent specializations in feeding (species, size, and depth of prey) that minimize direct competition between the components of the multispecies "school" (which also often includes yellowfin tuna). The two species (and the tuna) do indeed have different feeding habits in the eastern tropical Pacific, even in the same "school" (Perrin et al. 1973). In addition, Schnell et al. (footnote 4) found that expression of characters of the skull in *S. attenuata* that are associated with feeding is correlated with environmental parameters over long distances in the eastern tropical Pacific. For example, a correlation exists between size of the temporal fossa (through which the main jaw-closing muscle passes) and sea-surface temperature, solar insulation, and thickness of the oxygen-minimum layer. *Stenella longirostris* varies in a similar way. Schnell et al. concluded that "the rather marked morphological covariation between *S. attenuata* and *S. longirostris* involving a number of characters could reflect common causes associated with environmental spatial variation."

A conceptual model of the radial nature of the pattern of variation can be based on what we now know in a general way (Fig. 24). In this view, the animals in the far eastern Pacific (the eastern or Costa Rican spinner dolphins and, for the sake of argument, the offshore spotted dolphins north of the Equator and east of long. 120°W), and the dolphins in the central Pacific (Polynesia and points west) comprise the purest populations of the ecologically differentiated forms. Those in between (whitebelly spinner and offshore spotted dolphins south of the Equator and west of long.

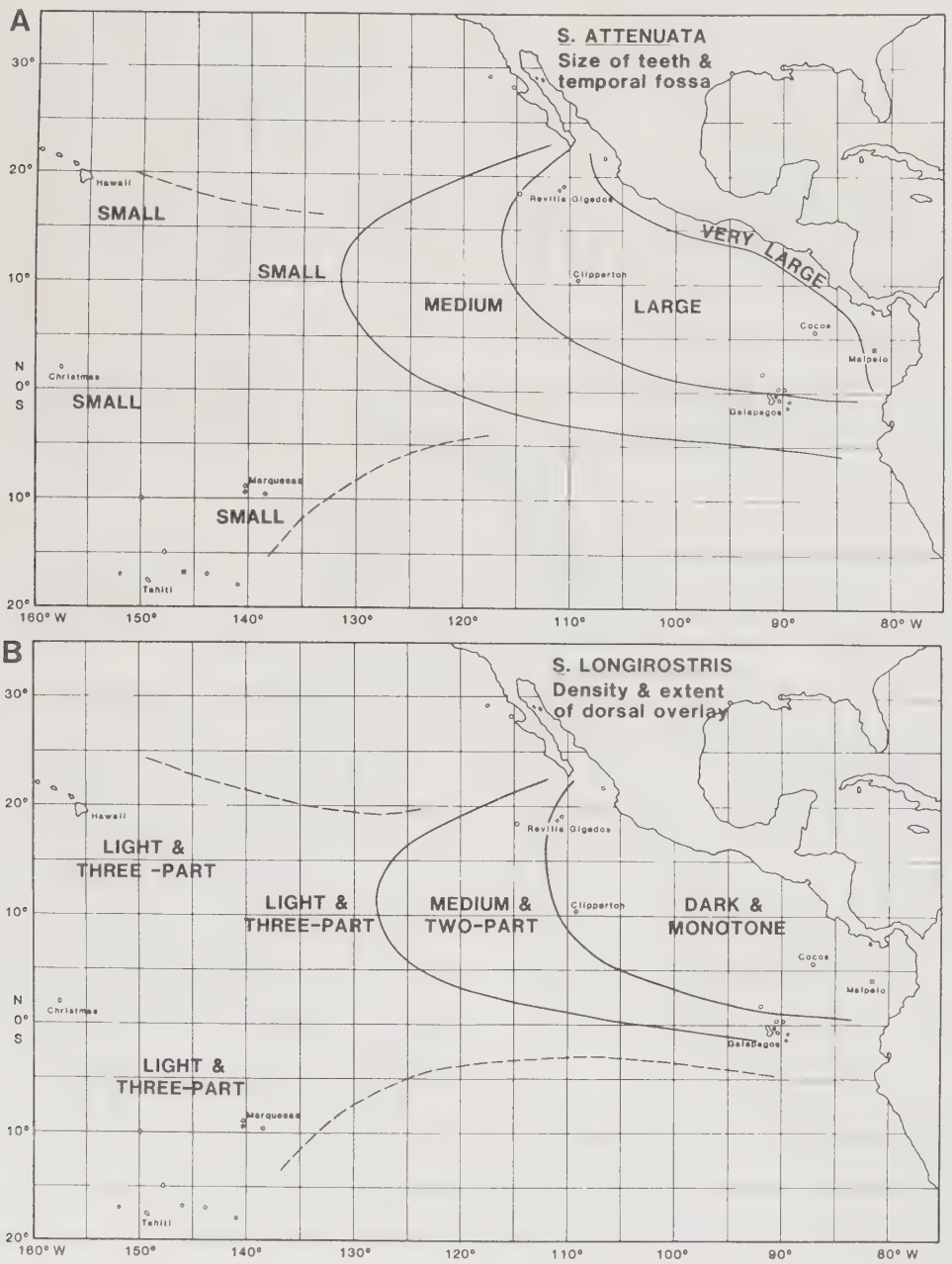


Figure 24.—Conceptual model of radial pattern of geographical variation in pelagic populations of *Stenella* A) *S. attenuata* and B) *S. longirostris* in the eastern tropical Pacific. Color pattern information from Perrin (1972a) and Perrin, Sloan, and Henderson (1979).

120°W) would thus comprise "hybrid" swarms. At least two historical scenarios can be suggested: differentiation during isolation of populations in the far-eastern Pacific by cool-water communication between the hemispheres during the glacial epoch (as has been suggested for the tropical Atlantic—Perrin et al. 1978), or existence, now or in the past, of selection pressures in the far-eastern Pacific sufficiently strong to give rise to differentiation without isolation by a physical barrier. In either case, the present situation of pronounced polymorphism could be stable or could be dynamic, e.g., introgression of central Pacific genes from the west could be neutralized by continuing strong selection pressures in the ecologically different eastern-Pacific, or the Indo-Pacific pool could be in the process of swamping out the eastern-Pacific differentiation. Lacking historical data, this of course is only speculation. Analysis of more osteological material from Polynesia may shed some light in relationships between animals there and those in the outer reaches of the eastern tropical Pacific.

RECOMMENDATIONS

Stenella attenuata

1) Schools should not be identified as "coastal" or "offshore" on the basis of position alone, because the ranges of the two forms overlap. Any school within 100 nmi of the coast for which size and degree of spotting of the animals is not determined should be relegated to unidentified status. If a management boundary is set inside 100 nmi to balance errors of identification based exclusively on position, it should take into account relative school sizes for the two forms as well as relative abundance of schools, in order to know what proportion of the population would be protected at various distances from the coast.

2) The northern and southern samples are clearly morphologically distinct. Although the spotted dolphins west of long. 120°W show affinities with those south of the Equator, and though the east-west and north-south variation may be broadly rather than sharply clinal, the present division of offshore populations into northern and southern units should be retained pending study of material from west of long. 120°W, from the equatorial region, and from Hawaii. Consideration should also be given to seasonal and year-to-year variation in oceanographic regimes north and south of the Equator and in the area between the two apparent centers of distribution.

Stenella longirostris

1) South of lat. 16°N, north of lat. 7°N, and within 50 nmi of the coast, schools of spinner dolphins should be assigned to "Costa Rican" or "eastern" based on modal body length and relative beak length. If this is not possible, they should be called unidentified spinner.

2) Identification of spinner schools as "eastern" (or "Costa Rican") or (northern or southern) "whitebelly" should be based on modal adult color pattern and modal dorsal-fin shape in adult males. Assessment and management of the two forms in the overlapping portions of their range should be an area-by-area basis (e.g., 5° squares, as in Figure 18).

3) As in the case of the spotted dolphin, the division of whitebelly spinners into northern and southern management units should be retained pending study of material from areas poorly represented in previous studies (near the Equator and in the far-western area) and comparison of the age structures of the northern and southern samples. Osteological material from Hawaii should be analyzed to determine relationships with animals in the eastern tropical Pacific. Seasonal and year-to-year oceanographic variation should also be considered in future definition of units.

Stenella coeruleoalba

A single provisional division into northern and southern stocks is recommended (Fig. 25). This is based solely on a hiatus in distribution, and existing osteological material should be analyzed.

Delphinus delphis

1) Within 100 nmi of the Pacific coast of Baja California and in the Gulf of California, schools of common dolphins should be identified as "Baja neritic" or "northern" (temperate/tropical) based on modal length, coloration, and relative beak length. If these features are not observable, the school should be classified as unidentified common dolphin.

2) Division into northern, central, and southern units is recommended (in addition to the Baja neritic stock, which is contained within the northern range) (Fig. 26). As the central-southern division is based on distribution alone, material from the southern area should be collected and compared with existing material from the central area.

3) Delineation of a "Guerrero" unit of common dolphins off southern Mexico is marginally justified pending study of material from the area.

ACKNOWLEDGMENTS

Nearly all of the data and specimens analyzed here were collected by government-employed biologists and technicians aboard commercial tuna seiners. Individual cruises lasted as long as 5 mo, and there have been more than 800 cruises. The labors and dedication of these people and the cooperation and assistance by the owners, operators, and crews of the tuna boats made this study possible.

We thank the following for critical review of the manuscript and the useful suggestions for its improvement: J. G. Mead, K. S. Norris, F. G. Alverson, G. D. Schnell, D. W. K. Au, A. E. Dizon, G. T. Sakagawa, and I. Barrett.

LITERATURE CITED

ALVERSON, F. G.
1981. Comments on the distribution of spotted, spinner, common and striped dolphin in the tropical Pacific Ocean. *In* P. S. Hammond (editor), Report on the Workshop on Tuna-Dolphin Interactions, Managua, Nicaragua, April 6-10, 1981. Inter-American Tropical Tuna Commission, La Jolla, CA, 259 p.

BANKS, R. C., and R. L. BROWNELL.
1969. Taxonomy of the common dolphins of the eastern Pacific Ocean. J. Mammal. 50:262-271.

BARLOW, J.
1984. Reproductive seasonality in pelagic dolphins (*Stenella* spp.): implications in measuring rates. *In* W. F. Perrin, R. L. Brownell, Jr., and D. P. DeMaster (editors), Reproduction in whales, dolphins and porpoises. Rep. Int. Whaling Comm. (Spec. Issue 6), p. 191-198.
In press. Variability, trends and biases in reproductive rates of spotted dolphins (*Stenella attenuata*). Fish. Bull., U.S.

DOUGLAS, M. E., G. D. SCHNELL, and D. J. HOUGH.
1984. Differentiation between inshore and offshore spotted dolphins in the eastern tropical Pacific Ocean. J. Mammal. 65:375-387.

EVANS, W. E.
1975. Distribution, differentiation of populations, and other aspects of the

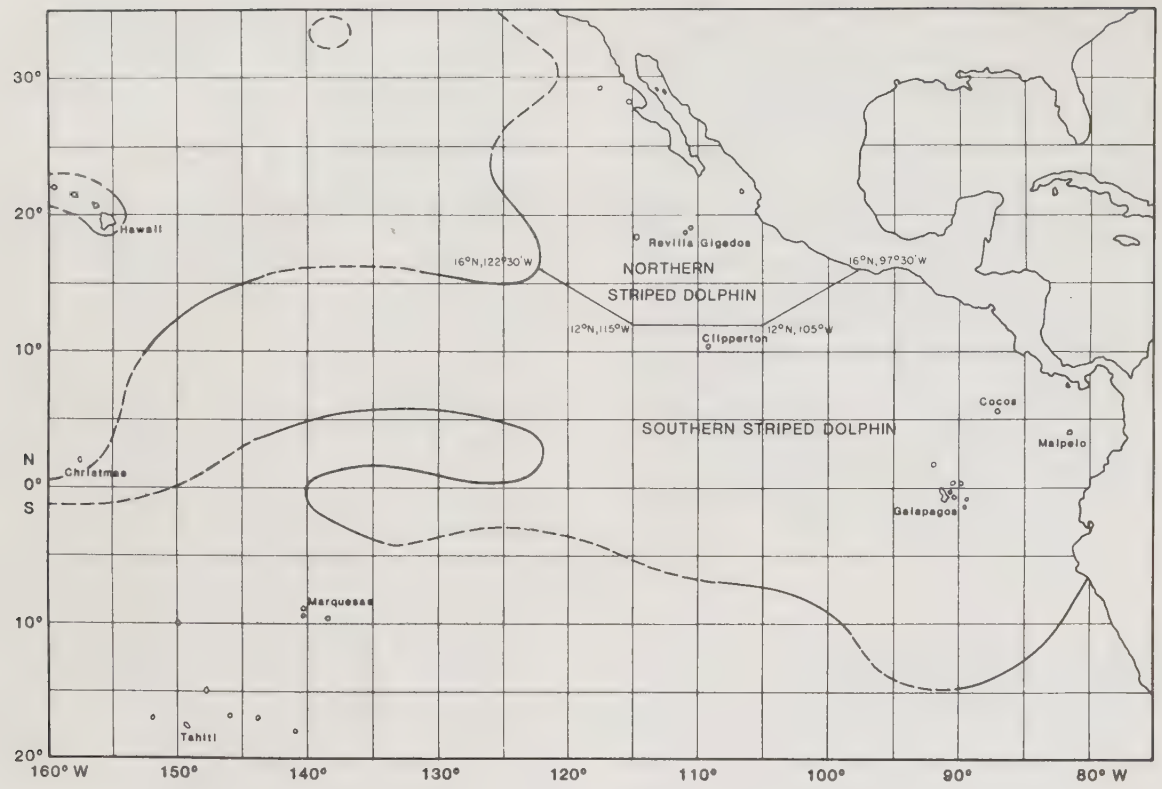


Figure 25.—Recommended management units for *Stenella coeruleoalba*.

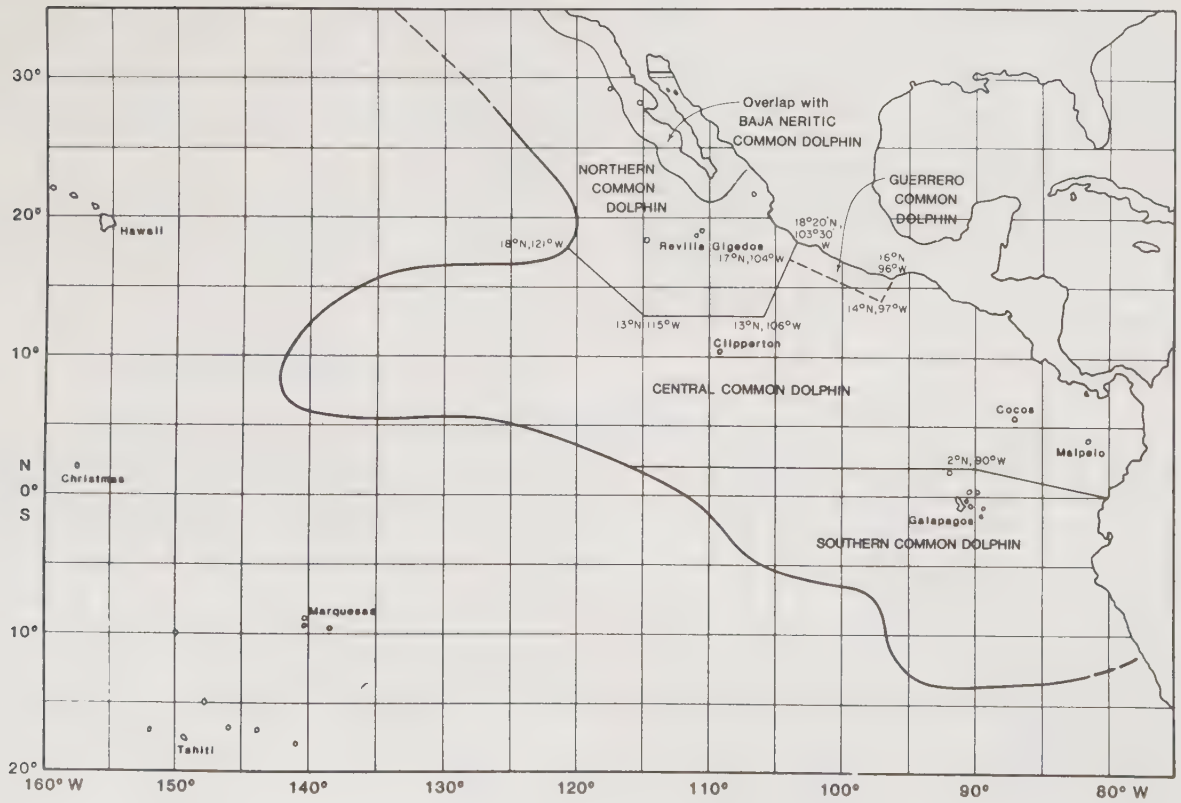


Figure 26.—Recommended management units for *Delphinus delphis* in the eastern tropical Pacific.

natural history of *Delphinus delphis* Linnaeus in the northeastern Pacific. Ph.D. Thesis, Univ. California, Los Angeles, 145 p.

1982. Distribution and differentiation of stock of *Delphinus delphis* Linnaeus in the northeastern Pacific. *In* Mammals in the seas, Vol. IV, p. 45-66. FAO, Rome.

HESTER, F. J., J. R. HUNTER, and R. R. WHITNEY.

1963. Jumping and spinning behavior in the spinner porpoise. J. Mammal. 44:586-588.

HOLT, R. S., and J. E. POWERS.

1982. Abundance estimation of dolphin stocks involved in the eastern tropical Pacific yellowfin tuna fishery determined from aerial and ship surveys to 1979. NOAA Tech. Memo. NMFS-SWFC-23, 95 p.

LEATHERWOOD, S., R. R. REEVES, W. F. PERRIN, and W. E. EVANS.

1982. Whales, dolphins, and porpoises of the eastern North Pacific and adjacent Arctic waters. U.S. Dep. Commer., NOAA Tech. Rep. NMFS Circ. 444, 245 p.

MORRIS, R. A., and L. S. MOWBRAY.

1966. An unusual barnacle attachment on the teeth of the Hawaiian spinner dolphin. Norsk Hvalfangst-tidende 55:15-16.

NORRIS, K. S., and T. P. DOHL.

1980. Behavior of the Hawaiian spinner dolphin, *Stenella longisrostris*. Fish. Bull., U.S. 77:821-849.

PERRIN, W. F.

1972a. Color patterns of spinner porpoises (*Stenella* cf. *S. longirostris*) of the eastern Pacific and Hawaii, with comments on delphinid pigmentation. Fish. Bull., U.S. 70:983-1003.

1972b. Variation and taxonomy of spotted and spinner porpoises (genus *Stenella*) of the eastern tropical Pacific and Hawaii. Ph.D. Thesis, Univ. California, Los Angeles, 490 p.

1975a. Variation of spotted and spinner porpoise (genus *Stenella*) in the eastern Pacific and Hawaii. Bull. Scripps Inst. Oceanogr. 21, 206 p.

1975b. Distribution and differentiation of populations of dolphins of the genus *Stenella* in the eastern tropical Pacific. J. Fish. Res. Board Can. 32:1059-1067.

In press. Patterns of variation in small cetaceans. Acta Zool. Fennica.

PERRIN, W. F., J. M. COE, and J. R. ZWEIFEL.

1976. Growth and reproduction of the spotted porpoise, *Stenella attenuata*, in the offshore eastern tropical Pacific. Fish. Bull., U.S. 74:229-269.

PERRIN, W. F., W. E. EVANS, and D. B. HOLTS.

1979. Movements of pelagic dolphins (*Stenella* spp.) in the eastern tropical Pacific as indicated by results of tagging, with summary of tagging operations, 1969-76. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-737, 14 p.

PERRIN, W. F., E. D. MITCHELL, and P. J. H. van BREE.

1978. Historical zoogeography of tropical pelagic dolphins. [Abstr.] II. Congr. Theriol. Int., Brno, Czechoslovakia, June 20-27, 1978, p. 73.

PERRIN W. F., and C. W. OLIVER.

1982. Time/area distribution and composition of the incidental kill of dolphins and small whales in the U.S. purse-seine fishery for tuna in the eastern tropical Pacific, 1979-80. Rep. Int. Whaling Comm. 32:429-444.

PERRIN, W. F., M. D. SCOTT, G. J. WALKER, F. M. RALSTON, and D. W. K. AU.

1983. Distribution of four dolphins (*Stenella* spp. and *Delphinus delphis*) in the eastern tropical Pacific, with an annotated catalog of data sources. NOAA Tech. Memo. NMFS-SWFC-38, 65 p.

PERRIN, W. F., P. A. SLOAN, and J. R. HENDERSON.

1979. Taxonomic status of the 'south-western stocks of spinner dolphin *Stenella longirostris* and spotted dolphin *S. attenuata*.' Rep. Int. Whaling Comm. 29:175-184.

PERRIN, W. F., T. D. SMITH, and G. T. SAKAGAWA.

1982. Status of populations of spotted dolphin, *Stenella attenuata*, and spinner dolphin, *S. longirostris*, in the eastern tropical Pacific. *In* Mammals in the seas. Vol. IV, p. 67-83. FAO, Rome.

PERRIN, W. F., R. R. WARNER, C. H. FISCUS, and D. B. HOLTS.

1973. Stomach contents of porpoise, *Stenella* spp., and yellowfin tuna, *Thunnus albacares*, in mixed-species aggregations. Fish. Bull., U.S. 71: 1077-1092.

SCOTT, M. D.

1981. Dolphin stocks in the eastern tropical Pacific. *In* P.S. Hammond (editor), Report on the Workshop on Tuna-Dolphin Interactions, Managua, Nicaragua, April 6-10, 1981. Inter-American Tropical Tuna Commission, La Jolla, CA, 259 p.

SMITH, T. D.

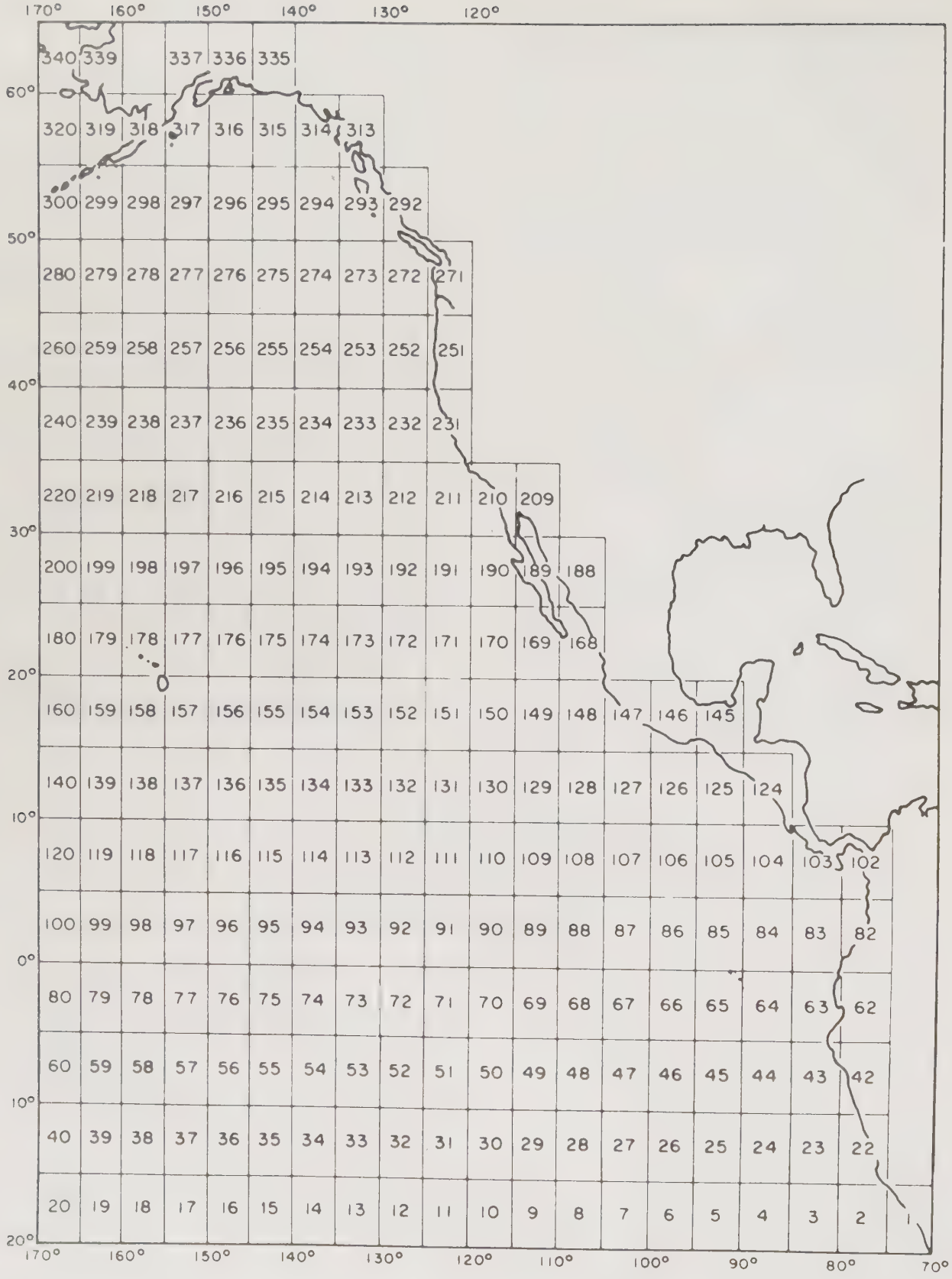
1983. Changes in size of three dolphin (*Stenella* spp.) populations in the eastern tropical Pacific. Fish. Bull., U.S. 81:1-13.

van BREE, P. J. H., and P. E. PURVES.

1972. Remarks on the validity of *Delphinus bairdii* (Cetacea, Delphinidae). J. Mammal. 53:372-374.

WHITE, M. J., Jr., J. G. JENNINGS, W. F. GANDY, and L. H. CORNELL.

1981. An evolution of tagging, marking, and tattooing techniques for small delphinids. NOAA Tech. Memo. NMFS-SWFC-16, 142 p.



Appendix 1.—Statistical reporting blocks (5°) for eastern tropical Pacific.

Appendix 2.—Stock composition of records of *Stenella longirostris* by 5° block (see Appendix 1 for locations).

Block no.	Costa Rican		Eastern		Whitebelly		Total identified	Unidentified		Total
	No.	% of ID'ed	No.	% of ID'ed	No.	% of ID'ed		No.	% of total	
3	0	—	0	—	1	100	1	0	—	1
23	0	—	0	—	26	100	26	1	4	27
24	0	—	3	7	37	92	40	2	5	42
25	0	—	0	—	16	100	16	0	—	16
26	0	—	0	—	4	100	4	0	—	4
43	0	—	0	—	13	100	13	5	28	18
44	0	—	4	2	167	98	171	16	9	187
45	0	—	0	—	97	100	97	5	5	102
46	0	—	0	—	31	100	31	1	3	32
47	0	—	0	—	1	100	1	0	—	1
48	0	—	0	—	1	100	1	0	—	1
54	0	—	0	—	2	100	2	1	33	3
55	0	—	0	—	1	100	1	10	90	11
63	0	—	1	3	29	98	30	29	49	59
64	0	—	3	7	41	93	44	13	23	57
65	0	—	0	—	102	100	102	22	18	124
66	0	—	0	—	32	100	32	6	16	38
67	0	—	0	—	57	100	57	6	10	63
68	0	—	0	—	21	100	21	1	5	22
69	0	—	0	—	13	100	13	0	—	13
70	0	—	0	—	9	100	9	0	—	9
71	0	—	0	—	1	100	1	0	—	1
72	0	—	0	—	1	100	1	0	—	1
73	0	—	0	—	2	100	2	0	—	2
82	0	—	1	13	7	87	8	2	20	10
83	0	—	18	37	31	63	49	37	43	86
84	0	—	24	26	67	74	91	49	35	140
85	0	—	15	8	183	92	198	55	22	253
86	0	—	9	5	162	95	171	31	15	202
87	0	—	22	12	155	88	177	24	12	201
88	0	—	17	5	310	95	327	23	7	350
89	0	—	2	2	131	98	133	13	9	146
90	0	—	4	5	82	95	86	17	17	103
91	0	—	0	—	70	100	70	4	5	74
92	0	—	0	—	29	100	29	2	6	31
93	0	—	0	—	2	100	2	2	50	4
102	0	—	6	67	3	33	9	14	61	23
103	9	6	75	56	49	37	133	82	38	215
104	2	2	60	51	55	47	117	80	41	197
105	0	—	51	47	57	53	108	70	39	178
106	0	—	236	70	99	30	335	164	33	499
107	0	—	220	61	142	39	362	167	32	529
108	0	—	169	43	220	57	389	172	31	561
109	0	—	42	31	95	69	137	46	25	183
110	0	—	25	24	81	76	106	34	24	140
111	0	—	26	10	233	90	259	62	19	321
112	0	—	21	5	378	95	399	57	13	456
113	0	—	12	3	345	97	357	57	14	414
114	0	—	8	3	294	97	302	28	9	330
115	0	—	1	1	81	99	82	7	8	89
116	0	—	0	—	1	100	1	0	—	1
117	0	—	0	—	2	100	2	0	—	2
124	3	9	25	74	6	17	34	36	51	70
125	0	—	653	92	54	7	707	494	41	1,201
126	0	—	789	91	74	9	863	294	25	1,157
127	0	—	664	93	53	7	717	190	21	907
128	0	—	932	88	132	12	1,064	297	22	1,361
129	0	—	481	86	78	14	559	132	19	691
130	0	—	229	76	74	24	303	88	23	391
131	0	—	70	35	129	65	199	58	23	257
132	0	—	60	16	312	84	372	73	16	445
133	0	—	27	8	306	92	333	55	14	388
134	0	—	6	6	101	94	107	6	6	113

Appendix 2.— *Continued.*

Block no.	Costa Rican		Eastern		Whitebelly		Total identified	Unidentified		Total
	No.	% of ID'ed	No.	% of ID'ed	No.	% of ID'ed		No.	% of total	
135	0	—	0	—	23	100	23	4	15	27
136	0	—	0	—	5	100	5	1	17	6
137	0	—	0	—	1	100	1	0	—	1
138	0	—	0	—	2	100	2	0	—	2
145	0	—	0	—	1	100	1	3	75	4
146	0	—	65	94	4	6	69	44	39	113
147	0	—	203	96	8	4	211	132	38	343
148	0	—	86	90	10	10	96	45	32	141
149	0	—	192	93	15	7	207	104	33	311
150	0	—	97	89	12	11	109	46	30	155
151	0	—	4	67	2	33	6	2	45	8
152	0	—	1	17	5	83	6	3	33	9
153	0	—	0	—	9	100	9	0	—	9
168	0	—	0	—	5	8	5	46	44	51
169	0	—	0	—	6	30	6	9	31	15
Total	14	0.1	5,659	50.7	5,496	49.3	11,169	3,579	24.1	14,748

Guidelines for Contributors

CONTENTS OF MANUSCRIPT

First page. Give the title (as concise as possible) of the paper and the author's name, and footnote the author's affiliation, mailing address, and ZIP code.

Contents. Contains the text headings and abbreviated figure legends and table headings. Dots should follow each entry and page numbers should be omitted.

Abstract. Not to exceed one double-spaced page. Footnotes and literature citations do not belong in the abstract.

Text. See also Form of the Manuscript below. Follow the *U.S. Government Printing Office Style Manual,* 1973 edition. Fish names, follow the American Fisheries Society Special Publication No. 12, *A List of Common and Scientific Names of Fishes from the United States and Canada,* fourth edition, 1980. Use short, brief, informative headings in place of "Materials and Methods."

Text footnotes. Type on a separate sheet from the text. For unpublished or some processed material, give author, year, title of manuscript, number of pages, and where it is filed—agency and its location.

Personal communications. Cite name in text and footnote. Cite in footnote: John J. Jones, Fishery Biologist, Scripps Institution of Oceanography, La Jolla, CA 92037, pers. commun. 21 May 1977.

Figures. Should be self-explanatory, not requiring reference to the text. All figures should be cited consecutively in the text and their placement, where first mentioned, indicated in the left-hand margin of the manuscript page. Photographs and line drawings should be of "professional" quality—clear and balanced, and can be reduced to 42 pices for page width or to 20 picas for a single-column width, but no more than 57 picas high. Photographs and line drawings should be printed on glossy paper—sharply focused, good contrast. Label each figure. DO NOT SEND original figures to the Scientific Editor; NMFS Scientific Publications Office will request these if they are needed.

Tables. Each table should start on a separate page and should be self-explanatory, not requiring reference to the text. Headings should be short but amply descriptive. Use only horizontal rules. Number table footnotes consecutively across the page from left to right in Arabic numerals; and to avoid confusion with powers, place them to the *left* of the numerals. If the original tables are typed in our format and are clean and legible, these tables will be reproduced as they are. In the text all tables should be cited consecutively and their placement, where first mentioned, indicated in the left-hand margin of the manuscript page.

Acknowledgments. Place at the end of text. Give credit only to those who gave exceptional contributions and *not* to those whose contributions are part of their normal duties.

Literature cited. In text as: Smith and Jones (1977) or (Smith and Jones 1977); if more than one author, list according to years (e.g., Smith 1936; Jones et al 1975; Doe 1977). All papers referred to in the text should be listed alphabetically by the senior author's surname under the heading "Literature Cited"; only the author's surname and initials are required in the author line. The author is responsible for the accuracy of the literature citations. Abbreviations of names of periodicals and serials should conform to *Biological Abstracts List of Serials with Title Abbreviations.* Format, see a recent Technical Report.

Abbreviations and symbols. Common ones, such as mm, m, g, ml, mg, °C (for Celsius), %, °/₀₀, etc., should be used. Abbreviate units of measures only when used with numerals; periods are rarely used in these abbreviations. But periods are used in et al., vs., e.g., i.e., Wash. (WA is used only with ZIP code), etc. Abbreviations are acceptable in tables and figures where there is lack of space.

Measurements. Should be given in metric units. Other equivalent units may be given in parentheses.

FORM OF THE MANUSCRIPT

Original of the manuscript should be typed double-spaced on white bond paper. Triple space above headings. Send good duplicated copies of manuscript rather than carbon copies. The sequence of the material should be:

FIRST PAGE
CONTENTS
ABSTRACT
TEXT
LITERATURE CITED
TEXT FOOTNOTES
APPENDIX
TABLES (provide headings, including "Table" and Arabic numeral, e.g., Table 1.—, Table 2.—, etc.)
LIST OF FIGURE LEGENDS (entire legend, including "Figure" and Arabic numeral, e.g., Figure 1.—, Figure 2.—, etc.)
FIGURES

ADDITIONAL INFORMATION

Send ribbon copy and two duplicated copies of the manuscript to:

Dr. William J. Richards, Scientific Editor
Southeast Fisheries Center Miami Laboratory
National Marine Fisheries Service, NOAA
75 Virginia Beach Drive
Miami, FL 33149

Copies. Fifty copies will be supplied to the senior author and 100 to his organization free of charge.

UNITED STATES
DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL MARINE FISHERIES SERVICE
SCIENTIFIC PUBLICATIONS OFFICE
7600 SAND POINT WAY N.E.
BIN C15700
SEATTLE, WA 98115

OFFICIAL BUSINESS

NOAA SCIENTIFIC AND TECHNICAL PUBLICATIONS

The National Oceanic and Atmospheric Administration was established as part of the Department of Commerce on October 3, 1970. The mission responsibilities of NOAA are to assess the socioeconomic impact of natural and technological changes in the environment and to monitor and predict the state of the solid Earth, the oceans and their living resources, the atmosphere, and the space environment of the Earth.

The major components of NOAA regularly produce various types of scientific and technical information in the following kinds of publications:

PROFESSIONAL PAPERS—Important definitive research results, major techniques, and special investigations.

CONTRACT AND GRANT REPORTS—Reports prepared by contractors or grantees under NOAA sponsorship.

ATLAS—Presentation of analyzed data generally in the form of maps showing distribution of rainfall, chemical and physical conditions of oceans and atmosphere, distribution of fishes and marine mammals, ionospheric conditions, etc.

TECHNICAL SERVICE PUBLICATIONS—Reports containing data, observations, instructions, etc. A partial listing includes data serials; prediction and outlook periodicals; technical manuals, training papers, planning reports, and information serials; and miscellaneous technical publications.

TECHNICAL REPORTS—Journal quality with extensive details, mathematical developments, or data listings.

TECHNICAL MEMORANDUMS—Reports of preliminary, partial, or negative research or technology results, interim instructions, and the like.

Information on availability of NOAA publications can be obtained from:

U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161